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Mode of Action of Sugar-Baited Fly Traps[1]

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The statement is frequently made that sugar attracts insects. This statement is based on the observation that dry sucrose or sucrose solutions exposed to access by insects are soon visited by large numbers. If one is willing to accept as a definition of attractant that which elicits a positive *directive* locomotor response (Dethier 1947) or the even broader definition of "attract" given by Webster, namely, to cause to approach, it is clear that the observation of an aggregation of insects at a given substance is not in itself conclusive proof that the substance has attracted them. Several alternative interpretations, some of which are elaborated below, are equally plausible. It is not enough to know that sugar is effective as a bait to which insecticides can be added; it is desirable to know something of the nature of the events transpiring, if for no other reason than to make the best use of all possible factors which may enter into these events.

If sugar is not an attractant, how then can one account for the increased number of insects which visit it? Were it truly an attractant, it would have to stimulate from some distance, however small. The physical properties of sucrose preclude such a possibility. The vapor pressure of crystalline sucrose is so low that it is usually recorded as zero. In aqueous solution the principal effect of sucrose is to lower the vapor pressure of the water. Experiments have been performed (Table 1, expt. 2) which show that the lowering of vapor pressure is without effect on the behavior of flies toward traps. Identical lowering of vapor pressure of water can be effected by a variety of compounds provided the molar concentrations are properly adjusted. In none of the cases tested did flies aggregate at these solutions. In the opposite kind of experiment in which the vapor pressure of water was variously lowered by the use of different molar concentrations of sucrose (Table 1, expt. 2) all vessels containing sucrose were visited by flies even though the lowering of vapor pressure was different in each case.

Even the most casual observation will reveal that flies are indefatigable explorers. Sooner or later they will have walked upon nearly every exposed surface within their area of activity regardless of whether or not the surface is attractive. If a surface is to their liking they tend to remain longer there than elsewhere. Thus, within a short time numbers will begin to accumulate in a preferred area, not drawn there by any specific attractive principle but brought merely by chance wandering and held by some acceptable stimulus in the sense that once within the preferred zone their rate of locomotion decreases. By this random ortho-kinetic behavior (Fraenkel & Gunn 1940) aggregations may be formed at dishes of crystalline sucrose or sucrose solutions.

This explanation would appear to be inadequate to explain the obvious effectiveness of traps baited with pure sucrose either solid or in solution. But here again the observed facts are amenable to interpretation without the alternative apparent but premature conclusion that sucrose itself has acted as an attractant. A few simple experiments will illustrate the danger of accepting the apparent interpretation. More important still, they prove that the factors entering into the operation of even the simplest trap are unexpectedly complex, and that the behavior of flies in this respect possesses some totally unexpected characteristics.

For these experiments the simplest kind of trap was employed (Fig. 1). It consisted of a drinking glass 16 by 7 cm. in the top of which rested a 60-degree glass funnel 7 cm. in diameter. Before insertion the stem of the funnel was cut off flush. Flies entered traps of this type with ease and escaped only with difficulty. Traps were placed in random order or latin square design in a screened cage 2 by $1\frac{1}{2}$ by $1\frac{1}{2}$ feet. A more or less constant population level of 1000 black blow flies, *Phormia regina* (Meig.), was maintained. Glass traps were employed because they reduced the number of uncontrollable variables (*e.g.*, in screened traps there is contact between flies inside and those outside), could be cleaned thoroughly with utmost ease, were simple in the extreme, could be readily modified, and presented most rigorous testing conditions. Protocols of typical experiments representing various conditions of testing have been chosen to illustrate salient points (Table 1). In twenty replications of each experiment the relative order of effectiveness within a set of comparisons never changed.

Under the conditions of testing which were employed, a trap containing dry sucrose or solutions of sucrose caught a much greater number of flies than empty or water-baited traps (Table 1, expts. 1 and 2). That this result did not derive from the effect of ortho-kinesis was shown by the fact that the escape rate from empty or water-baited traps was no greater than that from sugar-

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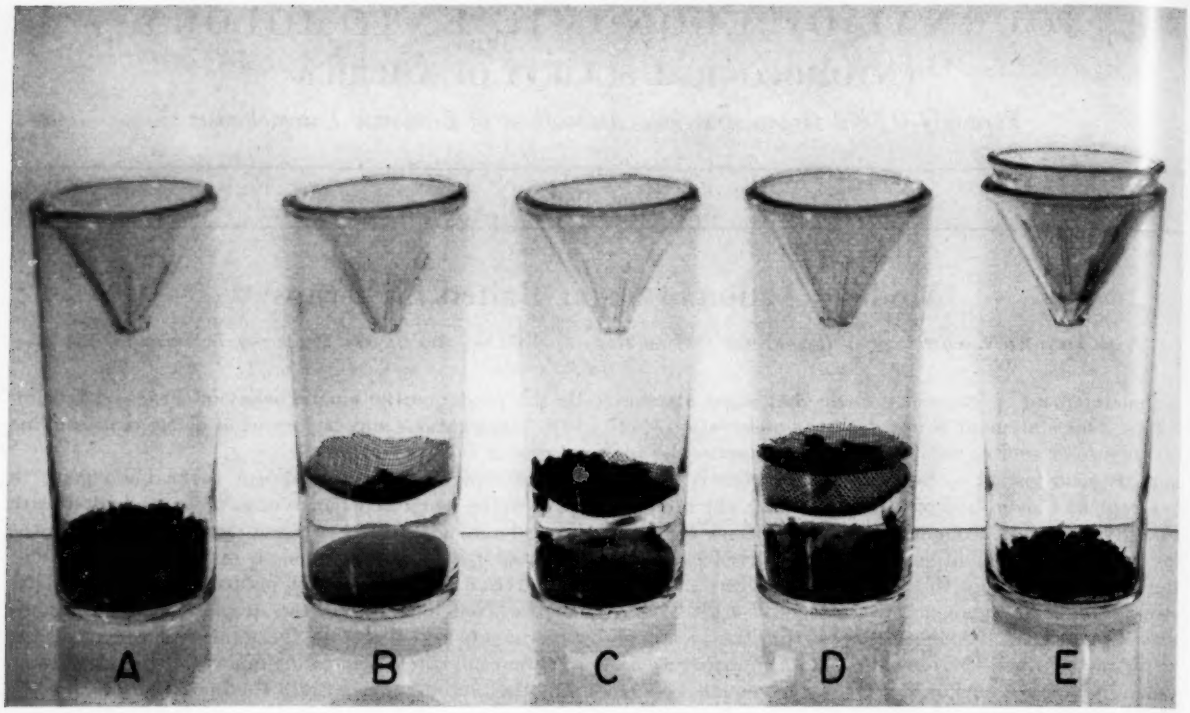

FIG. 1.—Various trapping arrangements employed in the study of the mode of action of sugar-baited traps. A, baited with dry sucrose; B, baited with dry sucrose beneath a wire screen partition; C, baited with dry sucrose and living flies beneath a single screen partition; D, baited with dry sucrose and living flies beneath a double partition; E, empty trap equipped with two funnels the top one of which was soiled by flies.

baited traps, *i.e.*, the sugar-baited trap was not merely "holding" flies which had arrived accidentally, as was the case with sugar exposed in the open; it was actually being visited by more flies.

On the other hand, two further experiments prove that *sugar* itself was not the attractant. If entering flies were removed as fast as they were trapped, the total number which had been removed at the end of any given period of time did not exceed significantly the number similarly removed from a water control (Table 2). Yet, when trapped flies were allowed to accumulate overnight the sugar trap made great gains (Table 2, last line). Inactivity in darkness greatly reduced the rate of entry to the water-baited trap, but the sugar-baited trap remained definitely attractive. It was a general rule that the longer the intervals were between successive emptying of the two traps, the greater the discrepancy in numbers caught by each.

The next experiment (Table 1, expt. 3) consisted of placing a wire screen partition in the trap above the sugar. Under this condition the trap then caught no more flies than the water control with or without a partition. If, however, captive flies were placed beneath the partition (Table 1, expt. 5), the trap now caught nearly as many flies as an unaltered sugar-baited trap.

The results of these experiments permit one to draw two conclusions at this point: (1) sucrose as such is not an attractant; (2) the first flies into a trap either add something odorous which renders the trap attractive or they communicate in some other manner with free flies on the outside.

Several different experiments were designed to determine whether the last alternative of the second conclusion was true. Vision was ruled out as a critical factor by the observation that rendering a trap opaque did not impair its effectiveness (Table 1, expt. 4). Auditory and olfactory communication were similarly ruled out by the observation that traps containing captive flies imprisoned beneath a double partition caught no more than the controls (Table 1, expt. 6).

In order that sugar-baited traps catch flies it is necessary, therefore, that the first individuals which are caught communicate with free individuals by contaminating through actual contact the entrance lip of the funnel or (by escaping) the outside surface of the funnel. When a trap was set with sucrose plus a few captive flies beneath a single wire screen partition, this trap was effective because the first chance arrivals were able to come in contact with the captives, which in turn were or had been in direct contact with sugar (Table 1, expt. 18). That is, a trap with sucrose plus live flies beneath a partition or an otherwise empty trap with *recently fed* flies beneath a single partition was effective (Table 1, expts. 5, 6, and 19). The addition of a second partition rendered the trap ineffective.

The final proof that contamination produced by or at least transferred by flies is an important factor in attraction is given by the following experiments. Funnels which had been removed from successful traps and placed on empty traps or on those baited solely with water caused

Table 1.—Black blow flies caught in experimental glass traps under various test conditions.

Experiment No.	Contents and Condition of Trap	Flies Caught in 24 Hours
1	Empty	12
	H_2O	14
	0.1 M sucrose	116
2	H_2O	9
	1 M lactose	10
	Dry sucrose	111
	1 M sucrose	75
	0.1 M sucrose	148
	0.01 M sucrose	150
3	H_2O beneath one partition	5
	0.1 M sucrose beneath one partition	4
4	H_2O in opaque trap	9
	0.1 M sucrose in opaque trap	152
5	0.1 M sucrose beneath one partition	6
	Freshly killed flies beneath partition	1
	Hungry flies beneath one partition	4
	Recently fed flies beneath one partition	47
6	Empty	0
	Killed flies beneath double partition	2
	Hungry flies beneath double partition	3
	Recently fed flies beneath double partition	1
7	Empty with clean funnel	57
	Empty with soiled funnel	123
8	Water with clean funnel	20
	Water with soiled funnel	162
9	Empty with clean funnel	10
	Empty, concave funnel surface swabbed with 0.1 M sucrose	41
	Empty, convex funnel surface swabbed with 0.1 M sucrose	11
10	0.1 M sucrose with soiled funnel cleaned on convex surface	210
	0.1 M sucrose with soiled funnel cleaned on concave surface	113
	0.1 M sucrose with clean funnel	71
11	H_2O with single funnel	21
	0.1 M sucrose with single funnel	109
	0.1 M sucrose with double funnel	82
12	Water with single funnel	16
	0.1 M sucrose with single funnel	46
	Water with double funnel, clean on top	6
	Water with double funnel, soiled on top	19
13	Water	13
	Water acted upon by trapped flies	14
	0.1 M sucrose	68
	0.1 M sucrose acted upon by trapped flies	231
14	0.1 M sucrose with one partition	9
	Water with one partition	10
	Water acted upon by flies, with one partition	11
	0.1 M sucrose acted upon by flies, with one partition	45
15[a]	Empty with clean funnel	37 *Phormia*
	Empty with funnel soiled by *Musca*	70 *Phormia*
16[b]	Empty with clean funnel	12 *Musca*
	Empty with funnel soiled by *Phormia*	57 *Musca*
17	0.1 M sucrose	54
	Sucrose acted upon by flies, one partition	62
	Sucrose acted upon by flies, one partition, flies beneath	101
	Sucrose acted upon by flies, two partitions, flies beneath bottom one	54
18	0.1 M sucrose	130
	Sucrose with one partition	4
	Sucrose with one partition, flies beneath	51
	Sucrose with two partitions, flies beneath bottom one	3
19	Empty	4
	Unfed flies beneath one partition	6
	Unfed flies beneath two partitions	1
	Fed flies beneath one partition	47
	Fed flies beneath two partitions	9

[a] This experiment was run for 18 hours.
[b] This experiment was run for 3 hours only.

those traps to catch more flies than controls with clean funnels (Table 1, expts. 7 and 8). The soiled funnels had obviously acquired something which either attracted in the true sense or held for a longer time those flies which had arrived by chance. Given more time for exploration the flies stood a better chance of eventually finding their way into a trap. It is easy to show that a substance which does no more than prolong the period of exploration on a funnel will lead to a greater number entering the trap.

Table 2.—Flies caught by sucrose and by water during each 30-minute period when not allowed to accumulate in traps.

Time	Gained per Period		Total at End of Each Period	
	Water	0.1 M Sucrose	Water	0.1 M Sucrose
9:25–10:00 A.M.	0	2	0	2
10:30 A.M.	1	1	1	3
11:00 A.M.	1	5	2	8
11:30 A.M.	1	2	3	10
12:00 NOON	2	1	5	11
12:30 P.M.	2	3	7	14
1:00 P.M.	0	0	7	14
2:00 P.M.	3	4	10	18
2:30 P.M.	1	7	11	25
3:00 P.M.	2	2	13	27
3:30 P.M.	2	3	15	30
4:00 P.M.	5	3	20	33
4:30 P.M.	6	5	26	38
5:00 P.M.	2	3	28	41
7:00 P.M.	2	4	30	45
overnight				
10:00 A.M.	5	80	35	125

Table 3.—Flies caught by empty traps with clean funnels and soiled funnels during each hourly period when not allowed to accumulate in traps.

Time	Gained per Period		Total at End of Each Period	
	Clean Funnel	Soiled Funnel	Clean Funnel	Soiled Funnel
9:15–10 A.M.	0	11	0	11
11 A.M.	2	3	2	14
12 NOON	0	1	2	15
1 P.M.	0	0	2	15
2 P.M.	1	1	3	16
3 P.M.	1	2	4	18
4 P.M.	1	2	5	20
overnight				
9 A.M.	8	120	13	140

An empty trap equipped with a funnel which had been swabbed with 0.1 M sucrose easily caught more flies than a control with a clean funnel (Table 1, expt. 9). The fact that a trap with a soiled funnel caught more flies per hour (Table 3) (captured flies being removed each hour) shows that something on the funnel itself, not the presence of increasing numbers of flies on the inside, was able to cause more flies to enter the trap. The effective contaminant was on the concave surface of the funnel only, *i.e.*, the surface exposed to the outside. Washing the convex surface of a soiled funnel did not impair its effectiveness; washing the concave surface did (Table 1, expt. 10). Covering a soiled funnel with a clean one also impaired its effectiveness, whereas a soiled one superimposed on a clean one retained its efficiency (Table 1, expt. 12). It must be noted as a general rule that traps with double funnels caught fewer flies than traps with single funnels (Table 1, expt. 11). This results from the disinclination of flies to enter through a double portal and from the difficulty of escaping.

It can further be shown that a soiled funnel lost its effectiveness rapidly unless the contaminant was constantly replenished. The hourly count (flies being removed at each count) dropped rapidly (Table 3). Within 3 to 4 hours the test trap caught no more than the control. If a freshly soiled funnel replaced the old, the hourly count immediately returned to a high value (Table 4). The loss of contaminant was not solely a result of removal by incoming flies, because a soiled funnel allowed to lie about lost its effectiveness in the absence of flies. The important component of the contaminant was, therefore, volatile.

From the results of the experiments described thus far it can be concluded that some of the first flies into a trap escaped after having come into contact with sugar or with captive flies under a partition who were themselves in contact with sugar; the escapees contaminated the exterior (funnel) of the trap.

But this cannot be the complete story. How do sugar traps build up and acquire soiled funnels in the first place? It can be shown that the first trapped flies which did not escape contributed something volatile to the trap which rendered it more attractive to others and that these in turn augmented the external contamination. If a sugar solution which had trapped a number of flies was filtered and the liquid free of flies returned to a clean trap, this trap caught more flies than a control containing a clean sugar solution (Table 1, expt. 13). The longer the flies had originally remained in the solution the more attractive it was. Three facts attest to the volatile nature and true attractiveness of the brew: (1) when placed beneath a single partition the brew retained its superior effectiveness (it will be recalled that sugar alone is ineffective under these circumstances) (Table 1, expt. 14); (2) on an hourly basis it caught more flies (these being removed periodically) than the controls (Table 5); (3) there was no diminution of effectiveness from hour to hour (Table 5).

The volatile substance which the trapped flies had contributed was not something generated directly by them but arose as a result of a reaction between something they produced and the sugar solution. This is suggested by the fact that a brew of freshly killed flies and sugar was a superior attractant, whereas a brew of flies and tap water was no more effective than water alone (Table 1, expts. 13 and 14).

The effect of contamination alone is similar to the effect of the odorous brew alone. For example, sugar-baited traps without partitions caught as many flies as brew-baited traps with partitions (Table 1, expt. 17). This can be explained in the first instance by the fact that the flies reached the sugar, then escaped and contaminated the funnel, while in the second case the partition prevented access to the brew and hence contamination of the funnel, yet the odor of the brew acted as an attractant. When the brew and contamination work together, attractiveness is enhanced. This effect is also illustrated

Table 4.—Flies caught by empty traps with clean funnels and soiled funnels during each hourly period when not allowed to accumulate in traps.

Time	Gained per Period		Total at End of Each Period	
	Clean Funnel	Soiled Funnel	Clean Funnel	Soiled Funnel
9:15–10 A.M.	3	40	3	40
11 A.M.	0	30	3	70
12 NOON	2	11	5	81
1 P.M.	3	22	8	103
2 P.M.	3	8	11	111
3 P.M.[a]	6	5	17	116
4 P.M.	2	14[a]	19	130
overnight				
9 A.M.	24	51	43	181

[a] Freshly soiled funnel replaced.

Table 5.—Flies caught by different solutions during hourly periods when not allowed to accumulate in traps.

Time	Gained per Period				Total at End of Each Period			
	Water	Water Brew	Sucrose	Sucrose Brew	Water	Water Brew	Sucrose	Sucrose Brew
10–11 A.M.	0	0	2	2	0	0	2	2
12 NOON	1	1	1	12	1	1	3	14
1 P.M.	1	0	6	14	2	1	9	28
2 P.M.	0	1	0	2	2	2	9	30
3 P.M.	1	0	1	13	3	2	10	43
4 P.M.	0	0	4	17	3	2	14	60
overnight								
9:15 A.M.	7	9	30	+250	10	11	44	+310

by experiment 17 (Table 1). When a trap was baited with brew and in addition with flies which were confined *between* two partitions, such a trap was more effective than either of the previous two, because the odor of the brew was attractive and in addition flies beneath the partition were able to touch entering flies which in turn contaminated the funnel. A control trap in which flies were confined *beneath* two partititions, hence were unable to contribute to the contamination, caught only as many flies as the ordinary brew-baited trap.

One has to do, then, with two substances each of which plays a part in making a sugar-baited trap attractive to flies. One is the material deposited on the funnel; the other, a material formed by the action of trapped flies on sugar solutions. The material deposited upon the funnel would appear at first glance to be a mixture of vomitus, faeces, and sugar transferred mechanically. The deposition of vomitus and faeces can be verified visually. The question of the presence of sugar was settled by appropriate tests. The funnel was washed with small volumes of distilled water, to which was then added dilute HCl. The mixture was incubated at 37° C. for 72 hours and then tested for reducing sugars with Benedict's solution and by the Somogy technique. These tests and the controls were negative; therefore, no appreciable amounts of sucrose or reducing substances had been present. If, however, the original washings were mixed with sucrose, incubated at 37° C for 72 hours, and then tested for reducing substances, the presence of an invertase could be demonstrated. While it is most unlikely that invertase is the attractive principle, its presence in such concentrations is surprising. The obvious conclusion is that invertase is ejected with vomitus. Nevertheless, the decision was made to test for its occurrence elsewhere, especially on the feet of the flies.

Flies were attached by the wings to wax-tipped applicator sticks. The mouth and anus of each insect was carefully sealed, and the flies stood in solutions of 0.1 M sucrose which were tested at intervals for the presence of reducing sugars. At the end of 1 hour at room temperature 10 ml. of sucrose exposed to 10 wading flies gave an extraordinarily strong positive reaction with Benedict's solution. Additional tests were conducted as indicated in table 6. Clearly an invertase is present on the legs of *Phormia* in appreciable quantity; it is not present in equal concentration elsewhere on the surface of the body; it is produced continuously by living flies.

The enzyme is produced in such quantity that a single fly in 1 hour can produce enough to give a strong positive test with Benedict's solution. Furthermore, the enzyme can be washed from the legs with distilled water. This is shown by the fact that water in which flies had stood (see last line of Table 6) could hydrolyze sucrose. Although the enzyme is not specific for sucrose, it hydrolyzes this sugar with greater rapidity than it hydrolyzes melezitose and raffinose. The order of decreasing effectiveness is sucrose, melezitose, raffinose. Tests with glucose, fructose, and lactose failed to reveal the presence of other enzymes.

Table 6.—Results of tests for the presence of invertase on bodies of flies.

TEST CONDITIONS	BENEDICT'S TEST OF SOLUTION
Living flies with legs in water	−
Living flies with legs in 0.1 M sucrose	+
Living flies with thoraces in sucrose	−
Living flies with wings in sucrose	−
Freshly killed flies with legs in sucrose	−
Isolated legs, with cut ends sealed, in sucrose	−
Living flies, with pulvilli sealed, in sucrose	slight
Water exposed to flies' legs for 4 hours	−
Water exposed to flies' legs, added to 0.1 M sucrose, incubated at 37° for 2 hours	+

As pointed out before, it is unlikely that the presence of invertase is in any way concerned with the effectiveness of the contaminant on traps. No further identification has yet been undertaken. Whatever the effective agent may be, it is not species-specific. Traps contaminnated by *Musca* caught large numbers of *Phormia* and vice versa (Table 1, expts. 15 and 16). It is more than likely that this substance is identical to the "fly factor" demonstrated by Barnhart & Chadwick (1953). The experiments reported here do not show whether the contaminant on the funnels is identical with the substance produced in the brew or whether the two are distinct. Experiments to settle this point and to discover the identity and origin of the fly factor or factors should be undertaken.

SUMMARY.—The effectiveness of sugar as a bait for the black blow fly, *Phormia regina*, is not due to its being an attractant in the true sense of the word. Aggregations of flies to exposed dishes of solid or dissolved sugar are brought about by means of an ortho-kinesis. Sugar-baited traps become attractive through the agency of the flies themselves. Flies escaping from traps leave a volatile contaminant on the outside of the trap entrance. Flies within the trap generate something which reacts with sugar to produce an attractive volatile brew. The contaminant is not species-specific. Flies also produce on their legs appreciable amounts of invertase which hydrolyzes sucrose, melezitose, and raffinose in decreasing order of effectiveness.

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Insecticide Tests against the Chinch Bug in the Laboratory[1]

NORMAN GANNON[2] and GEORGE C. DECKER[3]

Basically, the testing of insecticides against the chinch bug, *Blissus leucopterus* (Say), in the laboratory had two primary objectives. Several laboratory techniques were used to determine: (1) the relative toxicities of several insecticides to the chinch bug, and (2) the residual effectiveness of the various insecticides under test. It is assumed that materials which demonstrate little or no promise as chinch bug insecticides in the laboratory will not justify extensive testing in the field.

Literature pertaining to this particular problem is scanty. Kearns *et al.* (1949), by means of laboratory tests, demonstrated that dieldrin, aldrin, and γBHC were equal or superior to dinitrocresol in toxicity to the chinch bug and that heptachlor, chlordane, toxaphene, and DDT were less effective in the order named. On the basis of preliminary field tests, Decker *et al.* (1953) listed insecticides in descending order of their toxicity to the chinch bug as follows: parathion, lindane, dieldrin, endrin, aldrin, dinitrocresol, heptachlor, Dilan, chlordane, toxaphene, DDT, and TDE.

EXPERIMENTAL METHODS.—In determining the relative toxicities of various insecticides to the chinch bug, several techniques were used. The first of these tests entailed confining the bugs in treated pint ice-cream cartons for ½ hour, then removing them to petri dishes for observation. Fifty bugs were used in each treatment. The inner surfaces of each carton were treated by pipetting 10 c.c. of an insecticide-in-acetone solution into the carton, placing the lid on the carton, and swirling the solution around in it to cover all surfaces uniformly. The lid was then removed so the treated surfaces could dry. Concentrations of insecticides were expressed in mg. per sq. ft. Petri dishes used to house the bugs after treatment contained a disk of moist filter paper and a piece of young corn stalk upon which the bugs could feed.

The treated cartons were tested at varying time intervals after treatment to determine the residual effectiveness of the various insecticides. When not in use all cartons were kept open in a constant temperature chamber at a temperature of 85° F. The air in the chamber was constantly changed to remove any volatilizing insecticides by pumping in fresh air from the outside, thus forcing the stale air through an open exhaust.

In the second type of test, modified from a technique reported by Decker (1943), bugs were tumbled in loose, treated soil by means of a mechanical shaker. The soil was first sifted through a No. 20 U. S. standard sieve, which had openings measuring 840 microns. Forty mg. of the sifted soil was spread out in inverted petri dish covers and treated by pipetting 5 c.c. of insecticide-in-acetone solution back and forth over the surface. Concentrations were expressed in terms of mg. per sq. ft. When they were not being used in testing, the treated soil samples were also kept in a constant temperature chamber at 85° F. At specified intervals after treatment of the soil, bugs and treated soil were shaken for 15 minutes in corked 19×65 mm. shell vials. After shaking, the bugs were separated from the soil by sifting in small screen cages, and the soil was returned to the original dish for later use. Before testing at the different intervals the soil samples were stirred with a spatula to redistribute any recrystallized insecticide which may have formed on the surface. Tests were replicated five times, using 20 bugs per replicate.

A third test consisted of caging 20 to 50 bugs on packed treated soil for 24-hour periods, then removing them to petri dishes. The cages consisted of modified ice-cream carton lids. The ends were pushed out and fine brass strainer cloth, cut to fit, was inserted and sealed in place with paraffin. This allowed circulation of air inside the cages and thus eliminated the possibility of fumigation by the more volatile insecticides. The bottoms of the cages consisted of petri dishes containing the treated, packed soil. The tops were held firmly in place by means of cellophane tape. Included in the cages with the bugs at the time of exposure was a piece of young corn stalk and a piece of moist dental wick.

In all the tests, data were taken on the basis of live, moribund, and dead bugs. Observed mortalities were corrected for natural mortality by using the equation developed by Abbott (1925).

RESULTS AND DISCUSSION.—In the first experiments the insecticides were used at much higher dosages than would be used in the field, but the exposure periods were correspondingly shorter than they would be under field conditions. As shown in table 1, endrin was the most toxic material included in these tests, being about twice as toxic to chinch bugs as dieldrin and lindane. The latter two were about equal in initial toxicity, but dieldrin displayed greater residual effectiveness. Toxaphene at 12 times the dosage of endrin was practically ineffective, as was malathion at four times and chlordane at six times the concentration of endrin. Heptachlor and aldrin gave practically equal results at equal dosages, but according to this technique of testing they had to be used at roughly five to six times the rate of endrin to give comparable results.

Fourteen days after treatment, when bugs were exposed to the cartons for a period of 6 hours, all insecticides except chlordane and toxaphene gave practically 100 per cent control.

Nine days after treatment of the cartons, exposing bugs for 6 hours to a 12X concentration of toxaphene (623 mg.) resulted in control comparable to that obtained by a ½-hour exposure to a 1X concentration of endrin (52 mg.).

The results obtained in the second experiment or shaker test are presented in table 2. In the order of their effectiveness the materials line up about the same as in the previous test, but the more refined technique permits drawing more realistic comparisons of their relative toxicities.

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Table 1.—Mortality of chinch bugs 96 hours after a ½-hour exposure to ice-cream cartons treated as indicated.

Insecticide	Dosage (Mg./Sq. Ft.)	Corrected Per Cent Mortality: Days After Treatment of Carton 0	1	4	9	14
Endrin	52	100	96	90	75	63
	104	100	100	100	100	100
	208	100	100	100	100	100
Dieldrin	52	89	96	48	—	—
	104	87	100	94	69	85
	208	100	100	100	96	100
Lindane	104	100	85	18	—	—
	208	100	100	100	71	76
Heptachlor	208	91	100	94	33	46
	416	100	100	100	94	88
Aldrin	208	100	81	90	87	54
	416	100	100	90	96	95
Chlordane	156	70	0	6	—	—
	312	60	8	2	—	—
Malathion	104	71	42	6	—	—
	208	96	48	10	—	—
Toxaphene	208	2	27	—	—	—
	416	6	25	—	—	—
	623	2	8	19	—	—

When adult chinch bugs were shaken for 15 minutes in treated soil, endrin and parathion proved to be about equally toxic and were more toxic to the chinch bug than any of the other insecticides tested. As is shown in table 2, the relative amounts of each insecticide required to give a 95+ per cent mortality were: endrin 1, parathion 1, lindane 2, dieldrin 3, heptachlor 16, chlordane 32, toxaphene 32, and DDT 96. In supplemental tests not shown, endrin appeared to be 3 to 4 times as toxic as Isochlorthion and more than 16 times as toxic as Chlorthion to the chinch bug.

As is shown in table 3, the speed of action of the different insecticides when dosage was adjusted to give comparable high mortalities varied somewhat, but in general speed of action was closely correlated with relative toxicity.

The results obtained in the third set of experiments, in which bugs were confined for 24 hours on hard soil treated at dosages more closely approximating those suggested for use in the field, are presented in table 4. They show that all the insecticides tested except toxaphene and chlordane produced high or relatively high initial mortalities. Endrin, lindane, parathion, and dieldrin, used at equal dosages, all gave 100 per cent mortality. Heptachlor and aldrin, at three times that dosage, produced about 90 per cent mortality, and chlordane and toxaphene, at four times the dosage (of the first four), gave 68 and 50 per cent mortality, respectively.

Since shaker tests have shown that endrin was about three times as toxic to the chinch bug as was dieldrin and since both gave 100 per cent mortality when used at the same rate in the 24-hour exposure test, it seems reasonable to assume that one-third of the amount of endrin actually used would also have given close to 100 per cent mortality. If such is assumed to be true, then chlordane and toxaphene, at 12 times the presumed minimum effective dosage of endrin, still gave only 50 per cent

Table 2.—Mortality of chinch bugs 120 hours after a 15-minute shaking in soil treated as indicated.

Insecticide	Dosage (Mg./Sq. Ft.)	Corrected Per Cent Mortality: Days After Treatment of Soil 0	1	3	6	9	16
Endrin	212	100	100	—	100	—	98
	106[a]	100	95	—	97	—	100
	53	40	47	—	—	—	—
	27	47	29	—	—	—	—
	13	24	13	—	—	—	—
Parathion	212	100	99	100	99	100	95
	106[a]	98	99	90	85	78	81
	27	14	38	17	9	—	—
Dieldrin	424	100	—	98	—	100	100
	318[a]	100	—	88	—	97	99
	212	62	—	66	—	64	63
	106	33	—	17	—	22	—
Lindane	848	100	100	99	100	98	88
	212[a]	95	82	56	36	—	—
Heptachlor	3,394	98	100	97	100	100	98
	1,697[a]	96	73	—	—	—	—
	848	53	65	—	—	—	—
	424	50	55	35	17	—	—
Toxaphene	6,788	100	98	—	84	—	93
	5,091	96	87	—	—	—	—
	3,394[a]	100	100	—	88	—	71
	848	14	21	—	—	—	—
	424	5	7	—	—	—	—
Chlordane	5,091	98	98	—	—	—	—
	3,394[a]	97	87	76	56	—	—
	424	7	4	22	1	—	—
DDT	10,181[a]	88	70	—	—	—	—
	6,788	84	34	38	—	—	—
	848	7	3	3	—	—	—

[a] Dosages required to give 95 per cent or more initial mortality.

Table 3.—Speed of action as indicated by mortality at 24-hour intervals when chinch bugs were treated at dosage rates required to produce 95+ per cent mortality at 120 hours after treatment.

Insecticide	Dosage (Mg./Sq. Ft.)	Corrected Per Cent Mortality: Days After Treatment 1	2	3	4	5
Endrin	106	41.5	92.5	96.5	97	97.5
Parathion	106	45.5	82	93.2	97	98.5
Lindane	212	76	82.5	87	88	88.5
Dieldrin	318	42.5	68	82	87.5	94
Heptachlor	1,697	42	50.5	60	75.5	84.5
Toxaphene	3,394	14.5	46	76	93.5	100
Chlordane	3,394	28.5	58.5	76	85.5	92
DDT	10,181	36	46	48	61.5	79

Table 4.—Mortality of chinch bugs 120 hours after the initiation of tests in which the bugs were confined for 24 hours on firmly packed soil treated as indicated.

Insecticide	Dosage (Mg./Sq. Ft.)	Corrected Per Cent Mortality: Days After Treatment of Soil 0	1	4	8	13
Endrin	15	100	100	100	94	97
Lindane	15	100	100	92	88	54
Parathion	15	100	100	100	94	100
Dieldrin	15	100	88	73	56	81
Heptachlor	45	90	89	77	53	46
Aldrin	45	89	95	95	82	84
Chlordane	60	68	58	44	28	14
Toxaphene	60	50	66	51	8	27

control. How much chlordane or toxaphene would be needed to give 100 per cent control by this technique of testing is unknown, but it would not be surprising if it was in the realm of 30 times as much as the minimum dosage of endrin, or close to the ratio derived by means of shaker tests.

The long residual life indicated for lindane and parathion, unless attributable to overdosing, is not consistent with results obtained in field tests.

SUMMARY.—The data presented indicate that of all the insecticides tested endrin is perhaps best adapted to chinch bug control. Very small amounts of endrin gave high initial mortalities and its residues were among the most persistent. Parathion and lindane ranked with endrin and dieldrin in initial toxicity and speed of action but showed somewhat less persistence. The other insecticides tested, i.e., aldrin, malathion, heptachlor, chlordane, toxaphene, and DDT, were all materially less toxic to chinch bugs than those previously mentioned and might be regarded as less promising materials for barrier construction. Where subsequent migration is not a factor and the elimination of chinch bugs on corn or other crops is desired, at proper dosage levels most of the materials might be effective. Equivalent dosage rates are indicated as follows: endrin 1, parathion 1, lindane 2, dieldrin 3, heptachlor 16, chlordane 32, toxaphene 32, and DDT 96.

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Field Evaluation of Sprays for Chinch Bug Control[1]

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In the early summer of 1954 some wheat fields in central Illinois were seriously damaged by vast numbers of adult chinch bugs which had flown in from their overwintering quarters. Later in the season, although populations on the whole did not materialize to the extent anticipated, young chinch bugs did pose quite a threat to corn adjoining small grain in several areas of Illinois. Considerable testing of insecticides was carried out on both types of infestation.

This work was a continuation of preliminary work reported on by Decker *et al.* (1953). In tests conducted against light to moderate migrations they found that parathion, lindane, aldrin, chlordane, dieldrin, and endrin killed most of the bugs present at the time of spraying, but only dieldrin and endrin were residual enough to prevent reinvasion for more than 2 to 4 days. They determined that dieldrin was effective as a barrier for at least 10 to 14 days and that endrin was probably equally effective. Insecticides listed in the order of their toxicity to chinch bugs under field conditions were reported as follows: parathion, lindane, dieldrin, endrin, aldrin, dinitrocresol, heptachlor, Dilan, chlordane, toxaphene, DDT, and TDE.

MATERIALS AND METHODS.—When chinch bugs became sufficiently abundant to kill wheat early in the season, it was suggested that 0.5 lb. of dieldrin per acre be applied by airplane to several wheat fields. In one case, 0.5 lb. and 1.0 lb. per acre dosages of dieldrin were compared side by side in the same field.

Between 7 and 12 days after spraying four soil samples 6 inches square by 4 inches deep were taken from the sprayed and unsprayed areas in each of the treated fields. After the samples were brought into the laboratory, the bugs were separated from the soil by a flotation method, and the numbers of live, moribund, and dead bugs per sample were counted.

The insecticides tested against migrating bugs later in the season and their rates of application included dieldrin, parathion and lindane at 0.5 lb., endrin at 0.25 lb., aldrin and heptachlor at 1 lb., chlordane at 1.5 lb., and toxaphene and DDT at 2 lb. per acre. These materials were tested as barrier sprays in three fields; one having a light, one a moderate, and the third a heavy migration. Plots generally were 20 yards long.

Barrier strips were observed practically every evening from the date of treatment until migration was completed to determine the intensity of infestation and the length of the migration period. Data on barrier efficiency were obtained by rating the intensity and extent of infestations

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Table 1.—Control of adult chinch bugs as a result of applying dieldrin by airplane on wheat early in the season.

Field Number	Pounds per Acre	Date of Treatment	Date of Taking Data	Per Cent Moribund or Dead	
				Sprayed	Check
1	0.5	5-17	5-29	92	2
2	0.5	5-18	5-29	98	5
3	1.0	5-22	5-29	93	5
3	0.5	5-22	5-29	89	7
4	0.5	5-21	5-29	86	0

numerically. On the basis of bugs present, ratings 0 to 7 were assigned as follows: 0—none, 1—very light, 2—light, 3—light to moderate, 4—moderate, 5—moderate to heavy, 6—heavy, and 7—severe.

Each infested row of corn was rated from 1 to 7 and the ratings were totalled according to the number of rows thus infested. For example, if five rows along the edge of the field were classified as having a "heavy" infestation, the rating would be $5\times6=30$. If, on the other hand, 2 were "heavy," 2 were "moderate," and 1 was "light", the rating would be $(2\times6)+(2\times4)+(1\times2)=22$. An entirely clean plot received a rating of 0. In these three tests data were taken only from the five outer rows.

Data were also obtained on the effect of applying dieldrin at various times during the migration period and under other varying conditions. In one test a barley-corn border was divided into four parts. Each day for 4 days one of the divisions was sprayed with dieldrin at the rate of 0.5 lb. per acre, applying insecticide 2 rods into the barley and 2 rods into the corn.

Other dieldrin-sprayed barriers prepared by farmers in the area were also observed and notes were made on methods and care used in insecticide application as well as on the status of infestation and damage.

RESULTS AND DISCUSSION.—Table 1 shows the results obtained by spraying wheat to control adult chinch bugs which were abundant enough at egg-laying time to damage the crop seriously. General observations made in a number of commercially treated fields indicated equally good results. In all cases 0.5 lb. of dieldrin per acre applied by airplane gave excellent control of chinch bugs. Good results became evident 3 to 7 days after treatment, probably depending upon the influence of temperature on the activity of the bugs. Populations were so completely decimated in the treated fields that 10 days after treatment it was difficult to find live bugs. Young nymphs hatching from eggs quickly died and no infestations developed in any of the treated fields. On one farm where dosages of 0.5 and 1.0 lb. of dieldrin per acre were compared, the data indicated little advantage in using the higher dosage.

In the evaluation of sprayed barrier strips, several factors and viewpoints must be taken into consideration.

Table 2.—Ratings of insecticidal efficiency of different insecticides at daily intervals after spraying.

Severity of Migration	Insecticide	Pounds per Acre	Number of Days After Treatment—Ratings									Totals[a]	Order of Efficiency
			0	1	2	3	4	5	6	7	8		
Light	Endrin	0.25	24	1	4	—	—	—	0	—	—	5	1
	Dieldrin	0.5	24	2	4	—	—	—	0	—	—	6	2
	Aldrin	1.0	24	2	5	—	—	—	0	—	—	7	3
	Parathion	0.5	24	1	8	—	—	—	0	—	—	9	4
	Lindane	0.5	24	7	11	—	—	—	8	—	—	26	5
	Toxaphene	2.0	24	12	11	—	—	—	4	—	—	27	6
	DDT	2.0	24	10	16	—	—	—	8	—	—	34	7
	Chlordane	1.5	24	16	15	—	—	—	8	—	—	39	8
	Heptachlor	1.0	24	18	18	—	—	—	8	—	—	44	9
	Check	—	24	23	22.5	—	—	—	16	—	—	61.5	10
Moderate[b]	Dieldrin	0.5	27	3	3	3.5	3.5	6	14	12	19	13	1
	Aldrin	1.0	27	4	4.5	3.5	8.5	18.5	18	16	20	20.5	2
	Endrin	0.25	27	5	8.5	5.5	14	11.5	13	19	19	33	3
	Parathion	0.5	27	3.5	4	8	27	—	—	—	—	42.5	4
	Heptachlor	1.0	27	18.5	20	20	23	—	—	—	—	81.5	5
	Lindane	0.5	27	7.5	17.5	30	30	—	—	—	—	85	6
	Toxaphene	2.0	27	17.5	24	25	23	—	—	—	—	89.5	7
	DDT	2.0	27	20	23	28	30.5	—	—	—	—	101.5	8
	Chlordane	1.5	27	26	29.5	30	30	—	—	—	—	115.5	9
	Check	—	27	25	25	26	25	30	32	35	35	101	10
Heavy	Dieldrin	0.5	35	2.5	12	8	6	4	—	0	—	32.5	1
	Endrin	0.25	35	2.5	10	7	7	10	—	0	—	36.5	2
	Toxaphene	4.0	35	5	10	10	18	18	—	—	—	61	3
	Parathion	0.5	35	2.5	20	24	25	24	—	—	—	95.5	4
	Aldrin	1.0	35	20	21	20	22	22	—	—	—	105	5
	Chlordane	1.5	35	20	25	25	25	20	—	—	—	115	6
	DDT	2.0	35	15	30	28	30	25	—	—	—	118	7
	Lindane	0.5	35	5	30	28	30	30	—	—	—	123	8
	Heptachlor	1.0	35	25	30+	25	30	30	—	—	—	140	9
	Check	—	35	35	35+	31	34.5	34	—	—	—	169.5	10

[a] Totals were calculated only for the number of days for which comparative data were taken on every insecticide in each test.
[b] Field was cultivated 6 days after treatment.

Table 3.—Daily ratings[a] of the efficiency of 0.5 lb. of dieldrin per acre in controlling heavy chinch bug migrations.

Plot Number	Date of Treatment	Number of Days After Spraying—Ratings														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	6/29	50	—	—	31	53	43	22	10	10	0	0	0	0	0	0
2	6/30	10	—	20	32	20	20	23	15	20	5	0	0	0	0	0
3	7/1	10	2	15	20	19	30	30	25	20	15	10	0	0	0	0
4	7/2	5	2	2	14	22	33	27	20	22	20	23	12.5	5	5	0
5	None	40	50	55	60	70	70	70	70	60	60	50	50	50	40	40

[a] Ratings are on the basis of 10 rows of corn.

As shown in table 2, where light migrations were involved, the bug populations were low and all materials tested appeared at first glance to be good or at least satisfactory. Such was not the case, however, for on closer inspection of the data in table 1, one observes the order of efficiency is roughly the same whether the infestation was light, moderate, or heavy. The drop in ratings for the inefficient chinch bug insecticides on the sixth day of the light migration was probably caused by dispersion of the bugs rather than by their being killed by these insecticides.

The results obtained through the use of barriers against a migration of moderate intensity are also shown in table 2. Lindane was effective for only 1 day and parathion for 3 days, while dieldrin, endrin, and aldrin remained effective through the sixth day, at which time the field was cultivated. The aldrin treatment became slightly inferior to the other two by the fifth day after spraying. Barriers of chlordane, DDT, heptachlor, and toxaphene, at the dosages used, showed little or no advantage over the untreated check. Endrin at 0.25 lb. gave control comparable to that of dieldrin at 0.5 lb. per acre and was somewhat faster in its rate of action.

Against a heavy migration which had started an estimated 2 days before spraying (table 2), lindane and parathion were effective for only 1 day. Toxaphene, applied at 4 lb. per acre, gave good control for 3 days but began to fail on the fourth and fifth days and the population increased materially. Aldrin, under this heavy migration, produced only mediocre control while the heptachlor and chlordane plots had only slightly fewer bugs than did the check. Endrin and dieldrin again gave the highest degree of control attained. This does not mean that these two plots were entirely free of bugs throughout the migration period. Actually some live bugs were present in these plots at all times. However, their numbers were small compared to those in plots treated with less effective insecticides. The important points are these: First, the endrin and dieldrin plots were free of live bugs 2 to 3 days after migration was complete, thus indicating simply that it took some time to kill the bugs that moved into the corn. Secondly, no bugs got through these two barriers and remained alive long enough to damage the untreated corn beyond the barrier.

In another test dieldrin at 0.5 lb. per acre was applied at daily intervals in four plots (one plot each day) along a barley-corn border as previously described. At the initiation of spraying, only the first plot was infested, the bugs having moved into it in moderate numbers for 10 rows. When the other three plots were sprayed only small numbers of bugs were present on the outer rows (Table 3). Where migration had taken place before spraying, large numbers of bugs which were in the soil around the plants and protected behind leaf sheaths remained on the plants for a few days. Also in the face of continued heavy migrations some bugs got through to the first rows of corn but they lived only a day or so and none succeeded in reaching the clean untreated corn beyond the barrier. Much of the corn in the check area was devitalized and dying after the third or fourth day and except for a treatment applied farther into the corn the bugs would have destroyed many rows of corn.

Additional data on the length of migration periods, number of days after spraying that dying bugs were noted, etc., are given in table 4. It should be pointed out that all the ratings presented thus far have been on the basis of live bugs present on the exterior of the plants. The bugs present below the soil and under leaf sheaths were not included in the ratings. When control

Table 4.—Observations on farmer-treated fields where dieldrin at 0.5 lb. per acre was applied as a barrier spray against migrating chinch bugs.

Field Number	Intensity of Migration	Number of Days: Of Heavy Migration	Of Total Migration	To Clean Up Heavy Infestation above Ground	To Clean Up Totally	After Spraying Dying Bugs Were Noted
		Sprayed 2 Rods in Grain and 2 Rods in Corn				
1	Severe	8	10	8	11	17
2	Severe	9	11	11	14	17
3	Heavy	7	10	8	12	16
4	Heavy	8	10	9	11	15
5	Heavy	7	10	9	12	13
6	Heavy	6	8	6	8	16
7[a]	Moderate	7	9	11	12	11+
8[b]	Moderate	5	7	7	10	10+
9[c]	Light	4	5	4	6	9+
10[d]	Light	3	4	4	6	6+
Average		6.4	8.4	7.7	10.25	13.0+
		Little or no Spraying in the Grain[e]				
11[f]	Heavy	9	11	—	—	13
12[g]	Moderate	7	9	—	—	16
13[h]	Moderate	7	9	—	—	11
14[i]	Moderate	6	7	—	—	11
15[j]	Moderate	10	12	—	—	8+
16[k]	Moderate	8	9	7	—	8+

[a] No live bugs in plot 11 days after treatment.
[b] No live bugs in plot 10 days after treatment.
[c] Last record.
[d] No live bugs in plot 6 days after treatment.
[e] Never completely clean during observation period, except Field No. 16 as indicated.
[f] Bugs moving in later from barley across road confused results.
[g] One rod only sprayed into oats, migration started 1 week after spraying.
[h] One lb. dieldrin sprayed in corn only—none in wheat.
[i] One rod only sprayed into oats; migration started 9 days after spraying.
[j] Cultivated 7 days after spraying.
[k] One rod only sprayed into wheat. Last record.

measures were applied correctly, totally clean plants were generally evident within 3 days after the plants were free of bugs externally. The time varied depending upon the extent of movement of the bugs from untreated to treated surfaces and upon whether or not rains carried insecticide down to the bugs hiding and feeding beneath the soil or under the leaf sheaths. Only two very light rains (estimated to be 0.1 inch each) occurred during the entire treatment period. It was more or less apparent that many of the bugs that persisted longest were those which had migrated into secluded positions prior to spraying. Those which had to migrate across treated soil stood less chance of surviving.

The results presented in table 4 were obtained from fields in which dieldrin was sprayed as chinch bug barriers by farmers. The upper part of the table includes fields which were treated according to recommendations. The lower portion of the table gives observations on fields in which the control procedure differed from the recommended procedure in one or more ways. Most of the deviations pertained to the distance sprayed into the small grain. The recommended procedure consists of spraying at least 2 rods into the small grain with nozzles directed downward to spray the soil. Sprays on adjoining corn should be applied with drop nozzles so as to form a band covering the lower stalk and surrounding soil. This spray should be applied 2 rods into the cornfield or the distance to which bugs have penetrated, whichever is greater. The ends of the barrier should be capped with a spray swath 2 rods wide extending a few rods into both the wheat and the corn.

The most important point brought out here was the fact that dieldrin, when applied correctly, controlled chinch bug migrations of all intensities encountered in these tests. No case was observed in which it did not give a complete cleanup when the recommended method of control was followed. It appears possible, however, that in the presence of extremely high infestations or unusually adverse conditions more than one correctly applied treatment might be needed, e.g., unusually prolonged migrations of great intensity. Temperature may also be an important factor in the maintenance of a toxic residue, but in spite of 90° to 100° F. temperatures at the time of testing, the dieldrin barriers continued to kill bugs for as long as 17 days after treatment. The occurrence of rain after spraying may be either advantageous or disadvantageous, depending upon the circumstances under which it occurs. After the bugs are once located in the corn, with many beneath the soil level, a rain may be advantageous since it tends to carry the insecticide down into the soil around the base of the plants as well as into the leaf sheaths. On the other hand, where a good insecticide deposit is needed on the surface of the soil to prevent migration, any leaching or movement of insecticide into the soil might be undesirable.

The most common mistake which farmers made in attempting to halt chinch bug migrations was their failure to spray at least two rods into the small grain field. Also some farmers, who very conscientiously tried to control the bugs by spraying into the wheat, experienced poor control because of improper nozzle adjustment.

It should also be noted that many farmers who observed live bugs on the first rows of sprayed corn became panicky and resprayed unnecessarily. It was often difficult, if not impossible, to convince a farmer that those bugs were already doomed and would never make their way on into the corn field.

SUMMARY.—Early in the growing season, when chinch bugs had moved from their winter quarters into wheat in numbers great enough to seriously jeopardize the stand, good control was obtained with aerial applications of dieldrin at 0.5 lb. per acre. Not only was the immediate danger eliminated, but as a result young bugs never developed in these fields to threaten either the grain or the adjacent corn fields.

Of all the insecticides tested as barrier sprays, only endrin at rates of 0.25 to 0.5 lb. per acre and dieldrin at 0.5 lb. remained effective throughout the entire periods of migration. Parathion and lindane, both at 0.5 lb. per acre, gave excellent kills initially but were of no value in halting migrations two or three days later. Aldrin at 1 lb. per acre was effective against light to moderate migrations but was not effective against heavy migrations of long duration. Toxaphene at the rate of 2 lb. per acre was ineffective, but gave reasonably good results in one field when used at 4 lb. per acre. Heptachlor at 1 lb., chlordane at 1.5 lb. and DDT at 2 lb. were ineffective.

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Control of the Garden Centipede[1]

ANGUS J. HOWITT and R. M. BULLOCK[2,3]

For many years the garden centipede, *Scutigerella immaculata* (Newp.), has been a pest of greenhouse crops in Eastern, Central and Western United States. For at least the last 20 years it has caused damage of economic importance in California and Oregon. At present it is one of the most troublesome pests of field crops in Oregon and California. In 1953, it caused damage of economic importance in Washington for the first time. A survey conducted in 1954 showed this pest was present in many scattered localities throughout Washington.

The garden centipede is better known locally as the symphylid. Symphylids were of economic importance in areas adjacent to Vancouver, Spokane, Longview, Chehalis, Yakima, Puyallup, Walla Walla, and on Orcas Island in the San Juans. It is believed now that the symphylid has been present in Washington for some time even though it was not recognized as an economic pest until 1953.

During 1953 and 1954 a number of experiments were carried out at the Southwestern Washington Experiment Station, Vancouver, and in the vicinity thereof, to find a chemical control for symphylids. The results of this work are presented in this paper.

CHLORINATED HYDROCARBON EXPERIMENTS.—*Fall Treatments.*—The following procedures, in the order named, were employed in preparing and treating the plots prior to planting:

1. Plots were disked and treated September 22, 1953, with one-half of the insecticide-fertilizer mixture.

2. Plots were disked again, rototilled, then treated with the remaining half of the insecticide-fertilizer mixture.

3. Plots were disked again, rototilled and packed, then seeded to rye and vetch.

Rye and vetch were plowed under March, 1954. Plots were planted to Northwest strawberries April 1, 1954.

Three 10×40-ft. plots, and a 50×100-ft. plot, were treated with granulated heptachlor mixed with commercial fertilizer at 10 lbs. actual toxicant per acre. Similar plots were treated with granulated aldrin mixed with commercial fertilizer at 10 lbs. actual toxicant per acre. The plots were treated in September, 1953, and planted to strawberries in April, 1954.

Symphylid injury was first evident along the north edge of the plots which had been irrigated shortly after planting. By July 5th all plots had been irrigated. By August 1st, all plots were damaged by symphylids with approximately 75 per cent of the strawberry plants in all plots either killed or severely stunted.

Spring Treatments.—The following procedure, in the order named, was followed in preparing the plots prior to planting:

1. One-half the insecticide dosage was sprayed on the plots which were then disked, cross-disked, and plowed, April 1, 1954.

2. The remaining half of the insecticide dosage was applied, then the plots were disked, cross-disked and worked down before planting April 1, 1954. Morrison (1954) reported that, lacking rototillers, this method of tillage gave the best distribution of toxicants in the soil.

In March, 1954, four 30×100-ft. plots and two 54×100-ft. plots, were treated with toxaphene E.C. (emulsifiable concentrate) at 15 lbs. actual toxicant per acre. Similar plots were treated with aldrin E.C. and endrin E.C. at 10 lbs. actual per acre. The 54×100-ft. treated plots, two 54×100-ft. check plots and one-half of the 30×100-ft. plots were planted to raspberries. The remainder of the treated plots and two 30×100-ft. check plots were planted to strawberries.

Strawberry plantings in all plots showed injury ranging from 50 per cent loss in the check plots to 25 to 50 per cent loss in the treated plots. Injury was not so severe in the raspberry plots although all plots showed evidence of symphylid injury.

Soil Treatments and Root Treatments.—The procedure followed in preparing and treating the plots was the same as that described for the spring treatments.

Experiment No. 1. In April, 1954, two 35×210-ft. plots, and two 35×280-ft. plots were treated with toxaphene E.C. at 15 lbs. actual toxicant per acre. Similar plots were treated with endrin E.C. and heptachlor E.C. at 10 lbs. actual toxicant per acre. All treated plots, and four check plots, were planted to raspberries.

The roots of the plants in alternate rows, in all plots, including check plots, were dusted with one per cent lindane prior to planting. The plants were treated by enclosing the roots in a paper bag which contained 1% lindane dust. The bag was shaken until a maximum amount of lindane adhered to the roots.

Experiment No. 2. In April, 1954, 16 plots, each 40×45 ft., were treated with either heptachlor E.C. or aldrin E.C. at 10 lbs. actual per acre. The plots were arranged in blocks, each block consisting of four plots arranged lineally. Alternate plots in the blocks were treated with either heptachlor E.C. or aldrin E.C. All plots were planted to raspberries (Puyallup). Two border rows of Willamette raspberries separated each of the four blocks. The roots of the plants in one of the two border rows separating the blocks were dusted with 1% lindane, in the manner described in Experiment No. 1, prior to planting.

Experiment No. 3. In April, 1954, two plots, each 40×50 ft. were planted to strawberries. The roots of the plants in alternate rows were dusted with 1% lindane in the manner described above, prior to planting.

In Experiment No. 1, losses due to phytotoxicity of the

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lindane were severe. Many of the plants were killed and those surviving were severely stunted. The losses due to the lindane treatments obscured the effects of symphylid (if any) control due to soil treatments.

In Experiment No. 2 moderate populations of symphylids developed in both the aldrin- and heptachlor-treated plots. About 25 per cent of the raspberry planting was lost. An estimated 75 per cent of the plants were killed or severely stunted in the endemic areas that developed in both the aldrin and heptachlor plots. The raspberry plants, in the border rows dusted with 1% lindane, were severely stunted or killed.

In Experiment No. 3 plants in the rows dusted with lindane prior to planting died shortly after the planting or were severely stunted. Plants in the untreated rows were killed or stunted by symphylids some weeks later.

SCREENING EXPERIMENTS.—Morrison (1954) reported that chlorinated hydrocarbons gave erratic control of symphylids. The work described in this paper substantiates this report. Since the chlorinated hydrocarbons failed to control symphylids, it was decided to try other types of insecticidal compounds. Evaluation of insecticides has been difficult because symphylid infestations occur in peculiar "target areas" or "bullseyes" throughout a field. (Fig. 1) Infestations become progressively less severe away from the centers of these endemic areas. The size of these infested areas ranged from a few hundred square feet to an acre or more. Symphylid populations may move from season to season or within the same season.

Methods.—This peculiar pattern of symphylid distribution required special consideration in setting up experimental plots. The following experimental procedure was employed to solve this difficulty and facilitate testing many compounds under field conditions. The insecticides were applied to the surface of the ground in a 16-inch band throughout the length of the row and then rototilled or raked into the soil. The seed was planted down the middle of this band. At a distance of 3 feet, from center to center, a similar band of a different toxicant was sprayed or dusted, worked into the soil in the same manner, then seeded. Every third row was a check so that every treated row bordered on a check row (Fig. 2). Any modification of treatments, such as a seed treatment or furrow treatment, was included in an experiment.

FIG. 1.—Field of cauliflower showing bare spots and areas of stunted growth termed "target areas," caused by symphylid infestations.

FIG. 2.—Bush beans, rows 3 feet apart. The insecticides were applied as soil treatments in 16-inch bands, the beans planted in the middle of the band. Every third row was a check row.

Materials.—Using the method described above, 18 compounds were tested under field conditions. Table 1 lists the toxicants and rate per acre. All treatments were replicated 16 times using bush beans, and 8 times with corn as the test plants. Where radish was the indicator plant there were single replications for heptachlor, isodrin, cryolite, chlordane, aldrin, endrin, DDT, toxaphene, Ovotran and Sulphenone; two replications for malathion, parathion, and EPN; and 10 replications for the lindane treatment. Each replication in all plots consisted of 65 linear feet of row.

Of the materials tested parathion gave the most promising results. Malathion and EPN showed promise although

Table 1.—Insecticides tested for symphylid control at the Southwestern Washington Experiment Station, Vancouver, Washington, 1954.

FORMULATION	TREATMENT AND POUNDS ACTUAL PER ACRE
Malathion,[a] 4 lbs. per gal.	10 to Soil
Parathion,[a] 2 lbs. per gal.	10 to Soil
Heptachlor,[a] 2 lbs. per gal.	10 to Soil
Isodrin,[a] 6 lbs. per gal.	10 to Soil
Chlordane,[a] 6 lbs. per gal.	20 to Soil
Aldrin,[a] 2 lbs. per gal.	10 to Soil
Endrin,[a] 1.5 lbs. per gal.	10 to Soil
Toxaphene,[a] 8 lbs. per gal.	20 to Soil
DDT,[b] 50%	15 to Soil
EPN,[b] 27%	10 to Soil
Sulphenone,[b] 50%	100 to Soil
Ovotran,[b] 50%	25 to Soil
Cryolite	20 to Soil
Schradan,[a] 2 lbs. per gal.	4 foliage sprays
Systox,[a] 2 lbs. per gal.	16 foliage sprays
Am. Cyanamid 12008 (8 lbs. per 100 lbs. seed)	Seed treatment
Am. Cyanamid 12009 (8 lbs. per 100 lbs. seed)	Seed treatment
Lindane,[b] 25% (1½ ozs. per bushel)	Seed treatment

[a] Emulsifiable concentrate.
[b] Wettable powder.

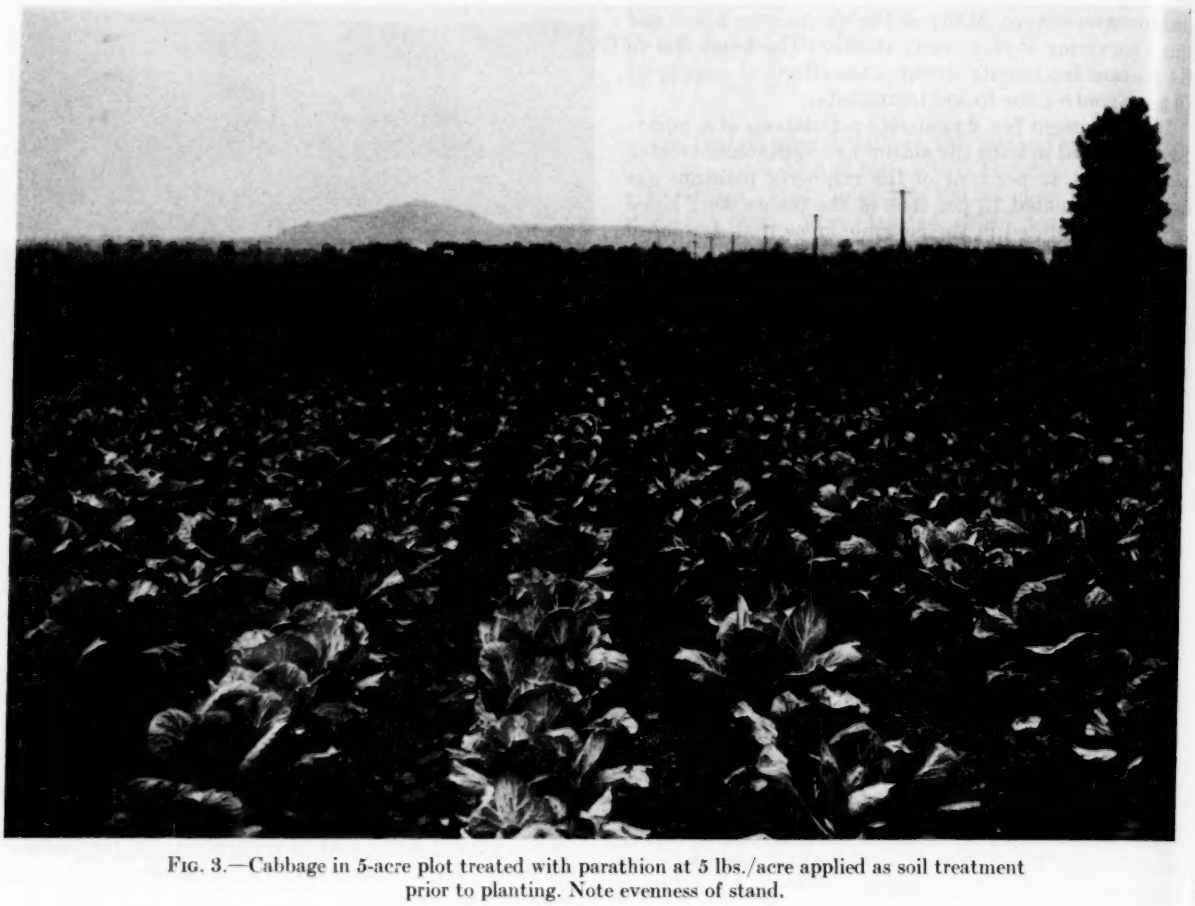

FIG. 3.—Cabbage in 5-acre plot treated with parathion at 5 lbs./acre applied as soil treatment prior to planting. Note evenness of stand.

they were not so outstanding as parathion. Isodrin gave the best results of the chlorinated hydrocarbons tested, but was inferior to the phosphates.

PARATHION EXPERIMENTS.—*Methods and Materials.*—To test parathion on a large scale, a 12-acre field was treated and planted as follows:

A five-acre plot was treated with parathion E.C. at 5 lbs. actual per acre and planted to Siedl cabbage; a 2-acre plot was treated with aldrin E.C. at 10 lbs. actual per acre, plus parathion E.C. at 5 lbs. actual per acre, and planted to Snowball cauliflower; a 2 acre plot was treated with aldrin E.C. at 10 lbs. actual per acre, and planted to Snowball cauliflower; a 1-acre check plot was planted to Siedl cabbage. The method of application and tillage was the same as described for the spring plots of 1954.

At the time of treatment, a very high population of symphylids was present in the field. Because of symphylid damage the grower had not been able to obtain a commercial crop from this land during the preceding 5 years.

Results.—To obtain quantitative data showing differences in growth and vigor between treatments, plants were measured and classified into four categories: 1. Normal—the plant showed normal growth; the head was well developed so that a normal head would be harvested.

Table 2.—Classification of plants for height and vigor in plots treated for control of symphylids at Vancouver, Washington.[a]

Insecticide and Pounds Actual/Acre	Normal	Stunted		Plants Missing	Total Plants	Average Height (Inches)
		Moderately	Severely			
		Cauliflower				
Aldrin, 10 plus parathion, 5	593	46	12	39	651	14.7
Aldrin, 10	235	99	159	207	493	9.7
		Cabbage				
Parathion, 5	512	34	8	36	554	14.0
Check	139	173	219	59	531	9.5

[a] Records taken October 6, 1954.

Table 3.—Percentage of plants normal, yields, and insecticide residues in plots treated for control of symphylids at Vancouver, Washington. November, 1954.[a]

Insecticide and Pounds Actual/Acre	Per centage Plants Normal	Crates/Acre	Residue (p.p.m)e
	Cauliflower		
Aldrin, 10	34	154	0.16
Aldrin, 10 plus parathion, 5	93	550	0.56
	Cabbage		
Parathion, 5	87	278	0.34
Check	24	42	0.18

[a] Treated July 7; planted July 10.

FIG. 4.—Cabbage in one-acre untreated plot. Note bare spots and areas of stunted growth.

FIG. 5.—Plot of cauliflower to the right of white stake was treated with aldrin at 10 lbs./acre; plot to the left of the white stake was treated with parathion at 5 lbs./acre plus aldrin at 10 lbs./acre.

2. Moderately stunted—the development was retarded to some extent. There was some chance of a head being harvested although it would be inferior. 3. Severely stunted—the plant was severely stunted and there was no chance of a head being harvested. 4. The number of plants missing in the cabbage plots was determined by subtracting the number of plants in each sample from the number of plants in the sample with the highest total. The figures given for the numbers of plants missing in the cauliflower plots were determined in the same way.

Data were obtained from five samples chosen at random in each plot. Each sample consisted of three adjoining rows, each 50 ft. long, or a total of 150 linear feet. Records were taken October 6, 1954, about 45 days before harvest. Table 2 gives the results showing the average height and the number of plants in each of the four categories for the different treatments.

Yield data were obtained from the grower on completion of harvest. Dr. W. E. Westlake, Chemist, Pesticide Chemicals Section, Entomology Research Branch, U. S. Department of Agriculture, Yakima, Washington, determined the residues of parathion by the method of Avrell & Norris (1948). Table 3 gives yield data, residues of parathion and the percentage of plants normal in each plot.

Discussion.—Parathion at 5 lbs. actual per acre gave outstanding results in the 5-acre field of cabbage (Fig. 3). No symphylids, or evidence of symphylid injury, were observed in this plot after treatment, and an excellent, even stand of cabbage was harvested. Cabbage in the 1-acre check plot was severely damaged by symphylids. A high symphylid population was present and many "target areas" developed in the plot (Fig. 4). Parathion at 5 lbs. actual per acre plus aldrin at 10 lbs. actual per acre gave outstanding control in the 2-acre plot of cauliflower. Since parathion alone at 5 lbs. actual per acre gave outstanding control in the cabbage plot, this precludes the possibility of synergistic action between aldrin and parathion being responsible for the control in the cauliflower plot. No symphylids could be found in the field after treatment, and no symphylid injury was observed. An excellent, uniform stand of cauliflower was harvested.

Aldrin at 10 lbs. actual per acre in the 2-acre plot of cauliflower failed to give control. A high population of symphylids was present throughout the growing season. Many "target areas" could be observed, and damage caused by symphylids was severe (Fig. 5). A great percentage of the original plants was destroyed by symphylids shortly after planting. These plants were replaced, and the replants also suffered severe damage.

Turnips planted in the plot treated with aldrin at 10 lbs. actual per acre were heavily infested with cabbage maggot, *Hylemyia brassica* (Bouché). Since aldrin at this high dosage usually gives good root maggot control on turnips, it may have deteriorated so as to lose its effectiveness. Farmers in surrounding areas failed to get symphylid control using aldrin at 10 and 20 lbs. actual per acre.

After harvest, weeds grew abundantly in the plots treated with parathion. The weeds, most chickweed, were unable to make any growth in the check and aldrin-treated plots due to symphylid feeding. Apparently, either the symphylids were slow in re-establishing themselves in the parathion-treated plots, or the parathion had a much longer residual effect than was expected.

SUMMARY.—Several experiments were carried out at the Southwestern Washington Experiment Station in the in the vicinity thereof to find a chemical method of controlling the garden centipede *Scutegerella immaculata* (Newp.) Fall treatments of granulated aldrin and heptachlor at 10 lbs. actual toxicant per acre and spring treatments using emulsifiable concentrates of toxaphene at 15 lbs. and heptachlor, endrin and aldrin at the rate of 10 lbs. actual toxicant per acre failed to give control in plantings of strawberries and raspberries.

A method is described for screening compounds for symphylid control in the field. Using this method, emulsifiable concentrates of malathion, parathion, heptachlor, isodrin and endrin at 10 lbs. and chlordane and toxaphene at 20 lbs. actual toxicant per acre, were tested as soil insecticides. Similarly wettable powders of EPN, cryolite, Ovotran, and Sulphenone were tested at 10, 20, 25, and 100 lbs. of actual toxicant per acre, respectively. Demeton or Systox and schradan were tested as foliage sprays by this method at the rate of 16 and 4 lbs. actual toxicant

per acre. Seed treatments, using Am. Cyanamid 12008 and Am. Cyanamid 12009 at 8 lbs. and 25% lindane wettable powder at 1½ ozs. per bushel of seed, were also included. Of the materials tested, parathion gave the most promising results. Parathion at 5 lbs. actual per acre, applied in July when the symphylids were near the surface, gave outstanding control in large plots of cauliflower and cabbage.

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Laboratory and Field Tests to Control Squash Bug[1]

J. M. WRIGHT[2] and G. C. DECKER[3]

Because the squash bug, *Anasa tristis* (Deg.), is one of the most annoying pests in home vegetable gardens and commercial squash and pumpkin fields throughout the United States, its control has been the subject of numerous investigations. Many research workers including Hoerner (1938), Dicke *et al.* (1945), Watkins (1946), and Gould (1954) have attacked this problem using a variety of insecticides and testing procedures. Some have reported fair success from several applications of moderately toxic materials or from materials which, although quite toxic to the squash bug, were expensive, difficult to obtain, and disagreeable to use. But there appears to have been no practical and economical control method evolved.

LABORATORY TESTS.—*Methods.*—The spotted infestation that occurred in the pumpkin-growing area of central Illinois in 1953 provided the first opportunity in several years to make preliminary tests of some of the newer insecticides against the squash bug. Adult bugs were collected from infested pumpkin fields after harvest, when the bugs were congregated on the remaining fruits and were easy to collect. The bugs were maintained in screen cages at room temperature in the laboratory with fresh squash supplied at intervals to provide food and moisture. Eleven insecticides were tested for their effectiveness against the adults. The technical materials were dissolved in acetone and applied topically with a micrometer-actuated hypodermic syringe. Ten bugs were used for each dosage and treatments were replicated three times, making a total of 30 bugs treated with each dosage of each material. Acetone-treated and untreated checks were run concurrently with treatments. After treatment the bugs were confined in clean half-pint ice cream cartons in which the top disk was replaced with screen. In the first tests a small cube of fresh squash was placed in each carton for food but it was noticed that very few of the treated or untreated bugs fed, so this was discontinued in later tests. All tests were run at room temperature.

Mortality was observed 12, 24, 48, and 72 hours after treatment. The bugs were considered dead when they no longer responded by moving their legs when pressed lightly.

To determine the relative residual toxicity of five of the more effective materials, adult bugs were exposed to the inside surfaces of half-pint ice cream cartons which had been treated with aldrin, heptachlor, lindane, parathion, and dieldrin at a dosage of 100 milligrams per square foot. The technical materials were dissolved in acetone and deposited on the inside surface of the cartons by allowing the solvent to evaporate. The cartons were constantly revolved so as to make the deposit as uniform as possible. The treated cartons were kept in a ventilated greenhouse with a temperature range of 68° to 78° F. The tests were run by confining 10 adult squash bugs in each treated carton. After 30-minute exposures, the bugs were removed to clean cartons. The bugs were exposed 7 days after the surfaces were treated and mortality was observed 24, 48, 72, and 96 hours after exposure.

Table 1.—Per cent mortality of adult squash bugs 72 hours after topical application of insecticides shown.

MATERIAL	DOSAGE IN MICROGRAMS PER GRAM				
	32	64	128	256	512
Parathion	100.0	100.0	100.0	100.0	100.0
Lindane	83.3	100.0	100.0	100.0	100.0
Aldrin		93.3	100.0	100.0	100.0
Endrin			100.0	100.0	100.0
EPN			100.0	100.0	100.0
Heptachlor		83.3	90.0	100.0	100.0
Isodrin			90.0	100.0	100.0
Dieldrin			70.0	100.0	100.0
Chlordane			36.7	80.0	90.0
Toxaphene			16.7	66.7	82.0
DDT			20.0	30.0	76.7

Results.—The relative effectiveness of the insecticides tested topically is shown in table 1. Parathion was the most toxic material, giving 100 per cent kill at a dosage of 32 micrograms per gram in 72 hours. Lindane was next in order of effectiveness. It was somewhat less toxic than parathion at a dosage of 32 micrograms per gram and a dosage of 64 micrograms per gram was necessary for 100 per cent mortality. Endrin, EPN, and aldrin appeared about equal in toxicity but required a dosage of 128 micrograms per gram to give complete kill. Heptachlor and

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FIG. 1.—A. Treated pumpkin field. B. Untreated pumpkin field. Photographs taken September 21, 1954.

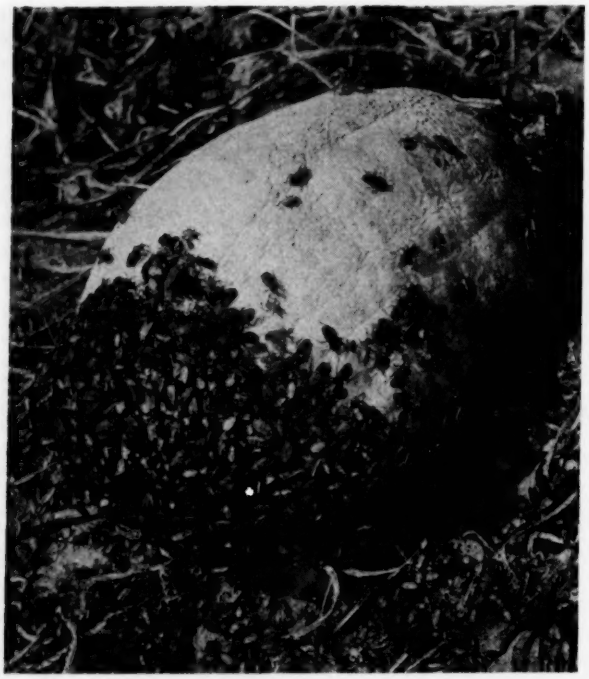

FIG. 2.—Squash bugs concentrated on withered pumpkin in untreated field.

isodrin were equal in toxicity but required a dosage of 256 micrograms per gram for 100 per cent kill. Dieldrin, though somewhat less effective than heptachlor and isodrin at a dosage of 128 micrograms per gram, also gave 100 per cent mortality at a dosage of 256 micrograms per gram. Chlordane, toxaphene, and DDT were much less toxic than the other materials and did not give complete mortality at the highest dosage used, 512 micrograms per gram.

Another indication of the relative effectiveness of these materials together with their speed of action is shown in table 2. In these data the rates of action are compared at the lowest dosage which gave 90 or more per cent mortality in 72 hours. The high toxicity of parathion was again demonstrated since 90 per cent kill resulted from a dosage of only 6 micrograms per gram.

Table 2.—Rate of action of insecticides shown[a] at lowest dosage required for 90 per cent or better mortality of adult squash bugs in 72 hours.

Material	Micrograms per Gram	Per Cent Mortality			
		12 Hours	24 Hours	48 Hours	72 Hours
Parathion	6	3.3	33.3	76.7	90.0
Lindane	64		80.0	100.0	100.0
Aldrin	64		23.3	76.7	93.3
Endrin	128	6.7	20.0	86.7	100.0
EPN	128	10.0	26.7	76.7	100.0
Heptachlor	128	10.0	50.0	80.0	90.0
Isodrin	128	0.0	10.0	63.3	90.0
Dieldrin	256	0.0	70.0	96.7	100.0
Chlordane	512		6.7	73.3	90.0

[a] Topical application.

Table 3.—Mortality of adult squash bugs[a] after 30-minute exposure to surface treated with insecticides shown at dosage of 100 milligrams per square foot.

Material	Per Cent Mortality			
	24 Hours	48 Hours	72 Hours	96 Hours
Dieldrin	30	80	80	100
Parathion	10	10	20	40
Lindane	10	20	20	20
Heptachlor	0	10	20	20
Aldrin	0	0	0	0

[a] Squash bugs exposed 7 days after surface was treated.

Lindane appeared to give the most rapid kill with 80 per cent mortality at 24 hours and 100 per cent mortality in 48 hours but at a dosage approximately 10 times that of parathion. At comparable dosages lindane was somewhat slower acting then parathion. Aldrin, although requiring the same dosage to give 100 per cent kill as endrin and EPN, appeared to be slightly more effective since 93.3 per cent mortality resulted from a dosage of 64 micrograms per gram. Heptachlor at a dosage of 128 micrograms per gram acted rather rapidly and gave 50 per cent kill in 24 hours but mortality at 72 hours was equal to that given by isodrin. Dieldrin also gave relatively high mortality in 24 hours, 70 per cent, but required a dosage of 256 micrograms per gram to cause 100 per cent mortality in 72 hours. Chlordane, at the high dosage of 512 micrograms per gram, gave only 6.7 per cent kill at 24 hours and 90 per cent kill at 72 hours. Mortality in the acetone-treated and untreated checks was negligible.

In residual tests dieldrin was by far the most effective material. Comparing the kills obtained from the materials used in residual tests (Table 3) with those in the topical application tests (Table 1), it appears that over a period of 7 days the effectiveness of parathion, lindane, heptachlor, and aldrin deposits is greatly reduced since exposure to these materials gave mortalities at 96 hours of only 40 per cent, 20 per cent, 20 per cent, and zero, respectively, while dieldrin gave 100 per cent mortality in 96 hours after exposure to a week-old deposit. No explanation for the complete failure of aldrin is offered. Under the conditions of this test it appeared that the parathion deposit was more effective than could be expected. However, since parathion showed high toxicity at very low dosages in previous tests, normal disappearance from a deposit of 100 milligrams per square foot could still have left a significant deposit after only 7 days.

Table 4.—Squash bug egg mass counts on pumpkin 4 days after treatment.

Treatment	Pounds Toxicant per Acre	Egg Masses per 10 Plants			
		North Half of Field	South Half of Field	Mean	Per Cent Reduction Over Check
Parathion	0.3	15.5	20.0	17.8	37.5
Dieldrin	0.5	14.0	25.3	19.6	31.2
Endrin	0.5	28.8	15.8	22.3	21.8
Aldrin	0.5	13.5	32.0	22.8	20.0
Lindane	0.25	18.5	31.5	25.0	12.3
Heptachlor	0.5	26.5	32.5	29.5	
Check		23.0	34.0	28.5	

Table 5.—Squash bug egg masses in plots of pumpkins receiving one or two applications of insecticide (July 8 and July 14.)

Treatment	Pounds Toxicant per Acre	Number of Applications	Egg Masses per 10 Plants							
			July 10	July 12	July 14	July 16	July 19	July 22	July 26	Aug. 6
Dieldrin	0.5	1	18.2	15.7	13.5	21.0	12.8	4.5	11.8	5.7
		2				11.8	11.0	4.0	5.8	8.7
Aldrin	0.5	1	22.5	17.8	14.2	25.2	31.3	8.8	13.5	20.0
		2				16.7	19.5	11.0	16.2	17.0
Parathion	0.3	1	18.0	19.3	17.8	41.3	28.3	25.5	38.3	56.0
		2				25.5	28.0	22.3	34.0	45.7
Check			37.5	35.7	33.3	50.5	43.2	39.3	44.8	43.0
						30.7	56.7	41.0	41.7	38.3
L.S.D. at 5% level		1	14.5	9.6	14.1	22.9	12.1	15.6	15.2	13.1
		2				9.3	21.5	10.7	20.8	19.8

Field Plots.—When it became apparent in 1954 that fairly severe infestations on pumpkin were imminent, two experiments, designated Test 1 and Test 2, were carried out.

Test 1.—This series of plots was treated as shown in table 4 with six of the materials having the greatest toxicity in the laboratory tests. The plots were 4 rows wide and 985 feet long, the length of the small field. Treatments were replicated four times in a randomized block arrangement. The sprays were applied July 2 with a four-row sprayer delivering 20 gallons per acre. The boom was equipped with one fan type nozzle per row. Parathion and lindane were applied as wettable powders, all other materials being in emulsion form.

Results were determined by counting the number of egg masses on 10 plants from the two center rows in each half of each plot. Counts were made on July 6, 4 days after treatment.

The egg counts are shown in table 4. Although only fair control was given by any of the materials after 4 days, there were indications that aldrin, dieldrin, endrin, and parathion offered some promise for controlling squash bug. Lindane failed to give the degree of control that might have been expected from the laboratory tests. Heptachlor at the dosage used was ineffective.

Test 2.—At the time egg counts were made on Test 1 it was apparent that a dangerous infestation was developing in fields throughout the pumpkin-growing area in central Illinois. Adults were migrating into nearly all fields and egg laying was rapidly progressing to a level that would require control measures. Even though results from all materials in Test 1 were only fair, a second series of plots was treated on July 8 with aldrin, dieldrin, and parathion since these materials, along with endrin appeared the most promising. Endrin was not included in Test 2 because of its relatively higher cost and limited availability for use on a commercial basis. A 30-acre field which had been planted late was selected for the second test.

To minimize inter-plot migration of adults the plots were made 16 rows wide. At the grower's request, the plots ran the entire length of the field, some 2052 feet, so that no damage would be caused by turning the sprayer. Treatments were replicated three times in a randomized block design.

All materials were applied with an eight-row self-propelled sprayer delivering 34 gallons per acre. The adjustable boom was equipped with two hollow-cone nozzles per row on drops and with the gallonage used gave excellent coverage of the plants. On July 14, half of each plot

Table 6.—Squash bug nymphs present in plots of pumpkin receiving one or two applications of insecticide.

Treatment	Pounds Toxicant per Acre	Number of Applications	Nymphs per 10 Plants						
			July 10	July 12	July 14	July 16	July 19	July 22	July 26
Dieldrin	0.5	1	2.7	6.7	3.7	30.8	73.5	16.3	8.7
		2				4.5	24.3	3.2	5.2
Aldrin	0.5	1	6.0	2.8	3.0	37.0	114.5	24.3	34.2
		2				8.0	30.2	11.5	18.5
Parathion	0.3	1	3.3	9.3	11.0	55.0	86.2	30.7	66.0
		2				5.0	38.0	7.8	18.5
Check			8.3	15.5	8.0	55.8	88.0	51.7	92.0
						10.3	40.7	18.8	55.3
L.S.D. at 5% level		1							62.5

Table 7.—Squash bug adults present in plots of pumpkin receiving one or two applications of insecticide.

Treatment	Pounds Toxicant per Acre	Number of Applications	Adults per 10 Plants						
			July 10	July 12	July 14	July 16	July 19	July 22	July 26
Dieldrin	0.5	1	1.3	4.8	1.0	2.7	4.5	1.2	2.7
		2				1.7	1.5	1.3	2.0
Aldrin	0.5	1	2.7	4.8	4.3	4.5	6.8	2.2	3.2
		2				3.7	4.2	1.7	1.3
Parathion	0.3	1	3.7	7.8	5.5	8.3	7.0	3.2	8.5
		2				5.3	8.5	3.7	8.5
Check			19.7	18.0	10.3	9.3	9.7	5.7	5.3
						9.8	9.0	5.0	6.3

received a second application of the same materials at the same dosages. Aldrin was applied in the form of a 23.1 per cent emulsion concentrate, dieldrin as a 15.8 per cent emulsion concentrate, and parathion as a 15 per cent wettable powder.

Counts of the number of egg masses, nymphs, and adults on 10 plants from the two center rows of each plot were made at intervals as shown in tables 5, 6 and 7.

Throughout the experiment it was very evident that dieldrin was giving excellent control of the squash bug. As may be seen in table 5, egg counts in the dieldrin plots were consistently lower than in any other plot. Fairly good control was given by aldrin. Egg counts in the parathion plots were comparable to those for dieldrin and aldrin for the first 8 days but were significantly higher for the remainder of the experiment, indicating that initial kill was obtained from parathion but that its lack of residual effect resulted in poor control after 8 days. Dieldrin, on the other hand, gave 87 per cent control, as measured by egg counts, 29 days after treatment.

Another indication of the effectiveness of dieldrin is shown by counts of nymphs (Table 6). Here again dieldrin gave better control than either of the other materials tested. Both aldrin and parathion gave fair to good initial kill but their effectiveness decreased after 8 days. Although it is not indicated in the table, half-grown or larger nymphs were consistently observed in the aldrin and parathion plots 11 or more days after treatment while only newly hatched nymphs could be found in the dieldrin plots until 18 days after treatment. Counts made later than 18 days showed only a very occasional larger nymph in the dieldrin plots.

Control of the adults was not so marked as that of the nymphs although good to fair kill was obtained from dieldrin and aldrin (Table 7). Adult populations in the treated plots remained at consistently low levels while the populations in the check plots consistently decreased, possibly indicating the amount of migration out of the untreated plots due to their deterioration.

A second application of each of the insecticides did not markedly affect the numbers of egg masses deposited although slightly better control resulted. Again the dieldrin plots contained the fewest eggs followed in order by aldrin and parathion.

As might be expected, the numbers of nymphs were greatly reduced by the second application. Nymph counts were much lower for all materials, with dieldrin again superior to aldrin and parathion. Adult populations were also further reduced by a second application of dieldrin and aldrin. No reduction resulted from a second application of parathion except for 2 days after treatment.

Although no harvest records were made it was very obvious that the dieldrin treatment gave spectacular increases in yield. Fields treated experimentally with dieldrin yielded what the farmers considered the highest quality and tonnage ever produced in the area while most untreated fields were either totally destroyed or were damaged so severely that they were not even harvested. Growers who saw the contrast between treated and untreated fields would not hesitate to use dieldrin for squash bug control if it were registered for that purpose.

SUMMARY AND CONCLUSIONS.—Laboratory tests involving topical application of 11 of the newer insecticides showed parathion to be highly toxic to adult squash bugs. Lindane was next in effectiveness and was somewhat less toxic than parathion. Endrin, EPN, and aldrin were about equal in toxicity. Heptachlor, isodrin, and dieldrin were next in order of toxicity and were approximately equal in effectiveness although dieldrin was slightly less toxic at lower dosages. Chlordane, toxaphene, and DDT were not effective.

The speed of action appeared to be in this same order except that aldrin was somewhat faster acting than endrin and EPN. Heptachlor appeared to act faster than isodrin but required the same dosage to give 90 per cent mortality in 72 hours.

When adult bugs were exposed to 7-day old deposits of dieldrin, parathion, lindane, heptachlor, and aldrin, dieldrin gave 100 per cent mortality in 96 hours and was by far the most effeetive material. Effectiveness of the other materials decreased in the order named.

Field tests demonstrated the superiority of dieldrin over all other materials tested. Far fewer eggs were laid in the dieldrin plots. Aldrin was intermediate between dieldrin and parathion. Abundance of eggs in the parathion plots rose sharply after 8 days. Dieldrin also gave better control of nymphs. Aldrin and parathion gave good initial kill but their effectiveness decreased after 8 days. Counts of the number of adults present in the plots showed only fair control by any of the materials although the fewer numbers of eggs laid in the dieldrin plots would indicate

that a large percentage of adults was being killed by that treatment.

A second application only slightly decreased the number of eggs laid although numbers of nymphs and adults were reduced. From these results it appears doubtful if the increased control was sufficient to warrant a second application. Observations in fields receiving only one experimental application of dieldrin bear this out. Where entire fields were sprayed and no portions left untreated, one application, whether by ground sprayer or airplane, gave excellent control of the squash bug.

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Ecology and Control of Soil Insects Attacking Corn in Illinois[1]

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During 1953 and 1954 an attempt was made to evaluate the importance of the seed and root infesting insects of corn in Illinois. At the same time considerable information was obtained indicative of the value of control of these insects to the operators of farms on the loam soils of the state. The tests were intended to gather information relative to the entire insect complex rather than any one or two insects. Both years were dry in the central part of Illinois and the southcentral part of the state suffered from severe drought in 1954.

The 1953 program consisted of observing and recording various data in corn fields on 26 farms where strips through fields had been treated with insecticide while the remainder of the field was untreated. Thirty-seven such comparisons were studied. The test fields were generally distributed throughout the northern half of Illinois. The work in 1953 was largely exploratory and served to guide the 1954 program.

During 1954 two types of observational material were available. Experimental plots using several insecticides were established in Champaign County. Ten sets of plots on four farms were in this category. A set of plots with only two materials was established in DeKalb County. There were also 103 comparisons between treated and untreated areas in the same fields on 82 farms distributed throughout the northern half of Illinois through the cooperation of farmers and commercial spray operators. In many cases in both years more than one field on a farm was treated or more than one comparison was obtained in the same field, such as where two or more insecticides were used in the field.

In all cooperative tests for both years the materials were applied by the farm operator or a commercial spray operator without supervision other than suggestions as to how to proceed. In a large number of cases the 1954 data were obtained from situations where the whole field except the untreated check strip received insecticide.

MATERIALS AND METHODS.—During 1953 aldrin was the only insecticide used in the tests. In 23 cases it was applied as a broadcast spray and disked into the top soil. Fourteen comparisons were available where the insecticide was applied in starter fertilizer mixture. Nearly all treated areas received a pound of aldrin per acre.

In 1954 aldrin at rates of 0.5 to 2.7 pounds per acre was included in 103 comparisons in 82 farmers' fields. Heptachlor at 1 and 1.5 pounds per acre in 7 comparisons in 5 fields, dieldrin at 1 pound in 2 comparisons in 2 fields and lindane seed treatment at 8 ounces per bushel in 1 field and 4 ounces per bushel in 14 fields were compared.

Applications on cooperators' fields were made by spraying either broadcast or over the row, by broadcasting of granules or by use of an insecticide-fertilizer mix hill-dropped or banded in the row at planting time. Aldrin was applied as a mix in liquid ammonia on one farm in 1954.

Six controlled experiments in central Illinois and one in northern Illinois were carried out where aldrin and heptachlor at 1.2 and 1.75 pounds, dieldrin at 1.1 to 1.4 pounds, and endrin and lindane at 0.5 to 0.66 pound per acre applied to the soil were compared. The insecticides were applied as emulsions sprayed on with a broadcast applicator and promptly disked in.

PLANT DATA SECURED.—During 1954 a preliminary survey was made in a few fields to show, at least in part, the numbers of residual insects present. A general survey was also made along a north to south highway running the length of the state. Fields were selected at random but at approximately 25-mile intervals. Fifteen fields were visited during the seedling stage of development and 25 plants were examined at each of four places in each field for apparent insect damage. Where the presence of subterranean insects was indicated 10 hills were dug to determine the insects involved.

During late May and June of both years data were collected in all fields relative to plant population and plant height. During 1953 four 25-hill samples were counted and measured in treated and untreated areas of each available comparison. During 1954 six such samples were taken in each plot. At the same time 5 to 10 five-hill samples were dug in untreated portions of the fields and,

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Table 1.—Populations of insects present in 5-hill samples in untreated areas of fields with different rotations, 1954.

Rotation	No. Fields Represented	Seed Beetles	Seed Maggots	Aphodius	Wireworms	Phyllophaga	Cyclocephala	Grape Colaspis	Ants	Aphids	Rootworm
First year corn											
Soybeans, 1953	7	0	0	0	1.1	0.5	0.5	0	0.14	0.14	0[a]
Small grain-legume, 1953	7	0	0	0.4	0.7	0.8	0	0.4	0	0	0[a]
Alfalfa-grass, 1953	7	0.3	0	0.6	1.5	0	0.6	1.3	0	0	0[a]
Legume mixture, 1953	2	0	0	2.0	0.3	0	0	14.0	2.0	2.0	0[a]
Wheat, 1953	3	0	0	2.3	2.7	0.3	0	0	0	0	0[a]
Ave. 1st yr. corn		0.04	0	1.1	1.2	0.2	0.13	2.3	0.3	0.3	0
Second year corn	9	1.3	2.2	0.2	4.4	1.7	0.3	0.3	0.3	0.2	26[b]
Third year corn	6	0.1	0.2	0	1.2	0.8	0	0.2	0	0	55[b]
Fourth year corn	1	0	0	3.0	1.0	1.0	0	0	0	0	0[a]
Fifth year corn	1	0	0	0	5.0	0	0	0	0	0	120[b]
Seventh year corn	1	0	0	0	2.0	0	14.0	0	0	0	207[b]

[a] All in central Illinois—northern corn rootworms found only in northern Illinois in 1954.
[b] Fields in northern Illinois only.

where appreciable numbers of insects were found, similar diggings were made in treated areas of the same fields.

During mid-summer of 1954 five 5-hill samples were dug in a number of fields where the presence of corn rootworms was suspected and the numbers of specimens present were recorded. Plant lodging was recorded in a few fields in 1953 and during 1954 in all fields where digging had shown rootworms present. Plants were considered lodged if the entire plant including the root system leaned 45 degrees or more from the perpendicular. Counts were made of 100-plant samples in five places in each plot in 1953 and six places in each plot in 1954.

During 1954, picker loss, as affected by rootworm lodging, was determined by counting dropped ears in six 50-hill samples in each plot following machine-picking of a field. Yield records were obtained both years both by hand-picking and in machine-picked plots. Hand-picked plots consisted of five 20-hill samples in each plot. Machine picking records were obtained from the cooperators who usually picked eight $\frac{1}{4}$-mile rows in both treated and untreated areas. The cooperators did not always pick replicated samples.

Data relative to the effect of other factors involved were collected: namely, time of plowing, time of disking, and method of application of insecticides.

Insects Present.—Prior to corn planting in 1954, three to five samples of soil 4 inches in diameter and 8 inches deep were taken from 16 different areas. These samples were from fall- and spring-plowed areas in one experimental field as well as from parts of fields representing 14 different rotations or plowing times on five farmer-cooperator farms.

The most generally distributed "residual" forms were Collembola, Japygids, mites, ants, and earthworms. The black-headed grass maggot, *Sciara* sp., was the most abundant of the larger insects. Wireworms were present in six and *Cyclocephala* in two of the 16 fields sampled. Microscopic examinations of soil from two fields in northern Illinois indicated mite populations ranging from 1,250,000,000 to 3,650,000,000 and Collembola populations ranging from 83 million to 500 million per acre. This type of sampling appears to offer promise only if carried out in a more thorough and intensive manner than it was possible to do in this case.

After the corn had emerged from the soil an attempt was made to determine the effect of crop rotation on the kinds and abundance of insects in untreated areas in the experimental plots and as many cooperators' fields as possible. First, up to 10 hills were dug in the untreated plot and, if a significant number of insects was obtained, replicate diggings were made in plots representing each of the treatments. This sampling was done from June 8 to July 30 and therefore could not accurately reflect the presence or absence of seed-corn maggots and seed-corn beetles. Typical seed injury was accepted as evidence of attack by these insects.

Wireworms were the most widely distributed of all the larger insects and, except for the northern corn rootworm the most numerous (Table 1). Two genera were represented, *Melanotus* and *Conoderus*. *Melanotus* were most numerous and damaging in three of the nine second-year corn fields examined. However, they were also quite numerous in one third-year and one fifth-year corn field as well as a first-year corn field that had been in soybeans in 1953. White grubs, *Phyllophaga* and *Cyclocephala*, caused severe injury in two corn fields that had been in soybeans in 1953. *Phyllophaga* larvae were abundant in one field in corn for the second year. It is thought that the number of white grubs found do not represent the number present, since *Cyclocephala* larvae were found only at a depth of over 10 inches and most samples were not taken that deep. The hot, dry weather of 1954 appeared to cause the larvae to go very deep in the soil. The same may have been true of wireworms, so that accurate counts were obtained only in those fields where diggings were made when the soil contained moisture and was not too warm. Grape colaspis larvae were abundant in only one field which had been in a legume mixture in 1953. Ants and aphids were found in fields where corn followed soybeans, a legume mixture, and in second- and third-year corn, but on the whole little damage by root aphids was detected.

Larvae of a small dung beetle, *Aphodius* sp., which has been suspected of attacking corn seeds on occasion were found in a number of fields. These larvae were found most often in first-year corn planted on land that had been pastured in 1953, although they were also found in fields of third- and fourth-year corn where the stalks had been pastured by cattle. Large numbers of adults were observed in November issuing from cattle manure in a

Table 2.—Apparent insect mortality resulting from treatment with different insecticides, 1954.

Insecticide and Pounds per Acre	No. of Tests[a]	Apparent Per Cent Mortality of: Wireworms	Phyllophaga	Cyclocephala	Northern Rootworm	Grape Colaspis	Ants	Aphids	Seed Beetle	Seed Maggot	Aphodius
Aldrin											
1	1 to 4	44	—	31	88	100	100	—	100	100	—
1.5	2 to 12	86	100	100	88	95	100	—	—	—	0
2	1 to 2	80	—	100	86	—	100	100	100	—	0
Heptachlor											
1	1 to 2	25	—	89	86	—	—	—	100	—	—
1.5	1 to 6	100	67	83	96	—	100	—	—	100	0
Dieldrin											
1	1 to 2	100	100	—	—	56	50	—	100	41	0
Endrin											
0.5	1 to 2	100	—	—	—	32	—	—	—	86	0
Lindane											
0.5	1 to 2	100	—	0	—	69	0	0	—	0	0
Lindane[b]	1 to 3	0	0	0	0	0	0	0	—	—	—

[a] Number in which any individual insect appeared.
[b] Seed treatment—4 oz. per bushel.

stalk field where cattle were being pastured.

Except for the fields where wireworms, white grubs or northern corn rootworms were observed to be damaging the corn, no single species of insect appeared to be very abundant. However, combinations of injurious insects were observed in 23 out of the 46 fields where untreated areas were sampled. These combinations included from two to as many as seven species.

Insect Mortality in Treated Plots.—The apparent insect mortalities due to applications of varying dosages of five insecticides are given in table 2. These mortalities represent the comparative numbers of the nine insect groups found in treated and untreated areas in both the controlled experiments and grower-cooperator tests.

It appeared in limited tests that 1 pound of aldrin per acre, sprayed on the soil and disked in, gave excellent control of the northern corn rootworm, grape colaspis, ants, seed beetles and seed-corn maggots and fair control of wireworms and *Cyclocephala*. One pound of heptachlor gave excellent control of the northern corn rootworm, *Cyclocephala*, and seed beetles but relatively poor control of wireworms.

In rather extensive tests of aldrin at 1.5 pounds per acre and limited tests of heptachlor at the same rate, both insecticides appeared to give excellent control of wireworms, northern corn rootworm, grape colaspis, ants and seed maggots. The aldrin gave good control of the seed beetle also, but heptachlor was not tested against it. Aldrin at 1.5 pounds gave excellent control of *Phyllophaga* and *Cyclocephala* in four tests, also, whereas, in a single test only mediocre results were secured with heptachlor against these insects.

In very limited tests 1 pound of dieldrin appeared satisfactory for the control of wireworms, *Phyllophaga*, and seed beetles but unsatisfactory for grape colaspis, ants, root aphids, and seed maggots.

Six-tenths pound endrin applied as a spray and disked in appeared satisfactory for wireworm and seed maggot control but unsatisfactory for grape colaspis.

Six-tenths pound lindane applied in the same manner also appeared satisfactory for wireworm and seed-corn maggot control, and moderately so for grape colaspis, but gave no apparent control of *Cyclocephala*, ants, and root aphids.

There were more plants cut by cutworms in experimental plots on the Reifsteck farm in the areas treated with 0.6 pound lindane per acre than in the untreated checks. Six-tenths pound of endrin, 1.1 pounds of dieldrin, and 1.75 pounds of heptachlor did not give significant reductions in the number of plants cut. Only aldrin at 1.75 pounds per acre gave significant reductions in the number of plants destroyed by cutworms. One cooperator obtained complete control of cutworms where he applied 1.25 pounds of aldrin per acre in the row with a planter-mounted sprayer. No insecticide at any amount used gave any apparent control of the dung beetle, *Aphodius*.

As a seed treatment at 8 ounces per bushel, lindane gave excellent control of a moderate infestation of wireworms in one test and failed in two others where only 4 ounces were used. It also failed to control *Phyllophaga*, *Cyclocephala*, northern corn rootworm, grape colaspis, ants, and root aphids. It was detrimental to plant growth in eight out of nine fields in which plant counts were made in treated and untreated areas.

Plant Population Counts.—Plant population records show averages of 1,021 and 742 more plants per acre in treated than in untreated areas in cooperators' fields where aldrin was used in 1953 and 1954 respectively, and an average increase for both years of 797 plants per acre. In 1954 heptachlor-treated plots showed 883 more plants per acre (Table 3). The average of all treated plots in 1954 was an increase of 749 plants per acre. The average numbers of plants per acre in untreated areas in 1953 was 10,709 and 11,373 in 1954. By using harvest data showing

Table 3.—Increase in plant populations in treated over untreated fields in 1953 and 1954.

Treatment	1953		1954		Average 2 Years	
	Number of Comparisons	Increase in Plants per Acre	Number of Comparisons	Increase in Plants per Acre	Number of Comparisons	Increase in Plants per Acre
Aldrin	37	1,021	103	742	140	797
Heptachlor			6	883		

number of ears obtained, and moisture content of the ears, and the number of barren plants, it was determined that theoretically an increase of 350 plants per acre in each year would increase production 3 bushels per acre, which is estimated to amply pay for the cost of treatment with either aldrin or heptachlor.

In 1953 there was an 8 per cent average increase in stand and 78 per cent of the fields showed increases that would theoretically pay the cost of treatment. In 1954 there was an average increase of 7 per cent, and 75 per cent of the fields showed increases that would theoretically pay the bill. The 1954 north-south survey showed approximately 7 per cent missing plants, and 78 per cent of the fields were found to have appreciable numbers of insects of one or more species.

Seven of the sets of experimental plots were in five fields on three farms of the same owner. In these plots (Table 4) aldrin and heptachlor treatments showed 11.3 and 9.7 per cent increases, respectively, in plant populations. Dieldrin, endrin, and lindane showed 7.4, 6.3 and 5.2 per cent increases, respectively. The three other sets of plots on another farm showed 7.9 and 9.4 per cent increases in plant populations in the aldrin and heptachlor plots. Dieldrin and endrin showed 6.3 and 5.0 per cent population increases. Average numbers of plants per acre on untreated areas of the two farms were 11,405 and 10,042, respectively. Lindane was not included in these plots. Insects were not as abundant on the fourth as on the first three farms.

On the Watson farm, in DeKalb County, 1.5 pounds each of aldrin and heptachlor were applied. On this farm the materials were not disked under immediately after application but the interval was shorter on the area treated with heptachlor than on that where aldrin was applied. These plots showed plant population increases of 524 and 1,264 plants per acre, 3.5 and 8.4 per cent for aldrin and heptachlor treatments, respectively. Plant populations in the untreated areas averaged 14,986 plants per acre.

Table 5.—Effect of soil treatment on abundance of northern corn rootworms and resulting plant lodging and picker loss.

	1953			1954		
	No. of Fields	Treated Area	Untreated Area	No. of Fields	Treated Area	Untreated Area
Larvae per hill	—	—	—	8	3.3	19.2
Per cent lodged	5	3.7	14.2	9	1.5	25.4
Dropped ears per plot				6	19.3	40.5

Plant Height.—Plant height data were collected at the same time that plant population counts were made. During 1953 measurements showed an average increase in plant height of 1.9 inches in the treated over the untreated areas. In 1954 the increase in plant height in treated areas averaged 1.5 inches. Very few fields showed appreciable height differences but in 1953 two fields showed about 5 inches difference, one field showed about 8 inches, and one field showed 11 inches difference. In 1954 twelve fields showed height differences of 4 or more inches with one of them having about 9 inches difference in height.

Rootworm Lodging.—In both 1953 and 1954 northern corn rootworms were found only in fields in northern Illinois despite the fact that adults were numerous in some fields in central and southcentral Illinois in 1953. In the northern area during 1954 an average of 5 larvae or pupae per hill was found in 3 fields in corn for the second year, and an average of 11 larvae or pupae per hill in 6 third-year corn fields. An average of 24 larvae or pupae per hill was found in one field in corn for 5 years, and an average of 41 larvae or pupae per hill was found in a field in corn for 7 years. Eight fields in corn for 3 or more years averaged 3 rootworms per hill in treated areas and 19 rootworms per hill in untreated areas. No rootworm counts were made in 1953 (Table 5).

Plant lodging resulted from the rootworm feeding only in fields in corn more than 2 years. In 1953, records of lodging were made in five fields and showed 3.7 per cent lodged plants in the treated areas and 14.2 per cent lodged plants in the untreated areas. The 1954 records on nine fields show 1.5 per cent of the plants lodged in treated

Table 4.—Plant population increases due to treatment with insecticides on experimental plots, 1954.

Treatment		Reifsteck Farms (3)[b]		Luyties Farm (1)[b]		Average 10 Plots	
Material	No. pounds per acre[a]	Number Plants per Acre	Per Cent over Check	Number Plants per Acre	Per Cent over Check	Number Plants per Acre	Per Cent over Check
Aldrin	1.75	1,284	11.3	796	7.9	1,173	10.9
Heptachlor	1.75	1,103	9.7	943	9.4	1,056	9.8
Dieldrin	1.1	846	7.4	629	6.3	781	7.3
Endrin	0.6	715	6.3	498	5.0	650	6.1
Lindane	0.6	592	5.2	—		—	
Average number plants in untreated areas		11,405		10,042		10,724	

[a] With some variation.
[b] Figure in parentheses indicates number of farms.

areas and 25.4 per cent lodged in untreated areas. During both years 1.0 pound of either aldrin or heptachlor was used on most of the rootworm infested fields.

EAR DROPPING.—The lodging of the plants results in greater loss of ears due to failure of mechanical pickers to garner some of those on the lodged plants. Measurements of this effect were made in six fields during 1954. Results are shown in table 5 and indicate that twice as many ears are lost in lodged areas as where plants are erect.

ALDRIN VS. HEPTACHLOR.—In 1954 it was possible to measure the comparative effect of aldrin and heptachlor in four cooperators' fields where each was used in equal amounts and was not complicated by other factors. Table 6 gives the data secured and shows that the average increases in plant populations in the four fields are not significantly different. Two of the fields received 1.5 pounds of insecticide in granulated form or broadcast spray. The other two fields each received 1.0 pound of insecticide as a broadcast spray.

SPRAY VS. FERTILIZER MIX.—On six fields it was possible to compare broadcast spray treatments with insecticide-fertilizer mix applications. The results are also shown in table 6 and indicate that there was no significant difference between these two methods of application. Apparent differences seemed to occur in individual fields in favor of one or the other method but these are erased by repeated observations.

SOIL VS. SEED TREATMENT.—In nine cases there were comparisons of soil and seed treatments with adequate checks. In seven of the nine cases plant populations were much larger in treated than untreated areas where soil treatment had been applied, but in eight out of nine times in the same fields the seed-treatment areas showed smaller populations in the treated area than in the untreated area.

EFFECTS OF CULTURAL PRACTICES ON RESULTS.—Portions of four fields observed in 1954 were plowed in the fall or winter of 1953 with the remainder of each field plowed in April or early May 1954. Plant population records show an increase of 524 plants per acre on the fall-plowed check strips over the spring-plowed check strips. The advantage for treating fall-plowed land is shown to be 590 plants per acre (Table 7) and for treating spring-plowed land as 1,153 plants per acre. There is a worthwhile increase in the number of plants in all of these situations.

Table 6.—Effects of treatments with different insecticides and different methods of applications, 1954.

METHOD OF APPLICATION	NO. OF TESTS	INCREASED NUMBER OF PLANTS PER ACRE IN TREATED OVER UNTREATED AREAS
All aldrin applications	4	781
All heptachlor applications	4	773[a]
Broadcast spray treatments	6	432
Fertilizer-mix applications	6	280[a,b]
Aldrin soil treatment	9	794
Lindane seed treatment	9	−1,153

[a] Differences between pairs not significant.
[b] This reflects at least in part a depressing effect of fertilizer in contact with the seed.

Table 7.—Effects of treatment on stand following two cultural practices, 1954.

METHOD OF TREATMENT	NO. OF TESTS	INCREASED NUMBER OF PLANTS PER ACRE IN TREATED OVER UNTREATED AREAS
Fall or winter plowing	4	590
Normal spring plowing	4	1,153
Prompt disking	3	2,227
Delayed disking	3	1,467
Advantage of prompt disking		760

In three fields it was found in 1954 that a portion of the field had not been promptly disked after broadcast treatment. These were fields where treatment was very valuable as shown by plant counts. In a portion of one field disking was delayed about 2 hours after treatment, in the others the delay was 3 to 4 hours.

Chemical analyses of the soil in one of the latter fields made 28 days after treatment showed only 0.05 p.p.m. of organic chlorine whereas three other fields treated at the same rate and where the insecticide was worked into the soil within an hour showed 0.3, 0.7 and 0.8 p.p.m. of organic chlorine. This would indicate that immediate coverage may be an exceedingly important part of any recommendation.

Table 7 shows that the plant increase for treatment in three fields which were disked promptly was 2,227 plants per acre and only 1,467 plants per acre in portions of the same fields where disking was delayed, an advantage of 760 plants per acre for prompt disking.

POSITION IN ROTATION.—During 1953 and 1954 a number of fields were observed that were planted to corn for from 1 to 7 years successively. The results, given in table 8, show variation from year to year but on the average there was little difference in plant population increases between fields in corn 1, 2, or more years.

YIELDS.—Yields were obtained in 17 fields during 1953 by hand picking small-plot samples. Yields ranged from a decrease of 9.6 bushels per acre in one case to an increase of 15.3 bushels and averaged 3.6 bushels per acre more corn on the treated then the untreated areas. Seven fields were havested with machines by cooperators. Yield in-

Table 8.—Effect of successive corn planting on stand in treated over untreated portions of fields.

YEARS IN CORN SUCCESSIVELY	1953		1954		AVERAGE 2 YEARS	
	No. of Comparisons	Increase in Plants per Acre	No. of Comparisons	Increase in Plants per Acre	No. of Comparisons	Increase in Plants per Acre
1st year corn	20	1,230	63	673	83	807
2nd year corn	12	653	23	1,074	35	928
3 or more years corn	4	742	17	721	21	726

creases for treatment ranged from 0.45 to 15.5 bushels per acre and averaged 7.7 bushels. Yields in untreated areas in the fields averaged 81.0 bushels per acre.

In 1954, hand-picked samples were harvested from plots in 12 fields. Yield differences ranged from a loss of 3.7 bushels per acre to a gain of 15.0 bushels per acre and averaged 3.5 bushels per acre increase on treated over untreated plots. Yields in untreated areas in these fields averaged 82.3 pushels per acre. Machine picking was done by cooperators in eight fields and showed an increase for treatment ranging from none to 10 bushels per acre, averaging 6.15 bushels for all plots. There were also three fields picked by a cooperator in the severe drought area which showed losses from 3.3 to 14.0 bushels per acre. These losses were associated with increased plant stands and reflect the excess demand for moisture of increased plant populations in the fields.

SUMMARY.—With moderate soil insect infestations, 1.5 pounds of aldrin or heptachlor apparently controlled the more injurious insects found in Illinois corn fields. One pound was sufficient for the northern corn rootworm but not all other insects. In very limited tests 1 pound of dieldrin showed the same trend. Approximately 0.5 pound of endrin or lindane was not sufficient.

Plant population increases were equal where aldrin and heptachlor were applied at equal dosages. Apparently the method of application was not important, although 1 pound sprayed over the row gave the same results as 1.5 pounds broadcast. The insecticide should be covered immediately after application. Soil treatment was much more effective than seed lindane treatment. Seed treatment reduced plant populations below the untreated checks in most cases.

In general yield increases resulted from treatment. However, in drought areas yield losses sometimes were associated with treatment. These losses are not ascribed to treatment but to the presence of more plants than the available moisture would support.

Organic Insecticides as Sprays for Armyworm Control[1]

NORMAN GANNON[2] and GEORGE C. DECKER[3]

The available literature is not in complete agreement regarding the effectiveness of certain insecticides in controlling the armyworm, *Pseudaletia unipuncta* (Haw.). Differences in methods of taking data, types of formulation, methods of application, and weather conditions are no doubt factors contributing to this disagreement. With specific reference to the efficiency or lack of efficiency of DDT, one observes that: Packard (1946) reported poor kills with DDT sprays at 2 lb. per acre as well as with 2 per cent and 10 per cent dusts used on tall, headed-out rye. Smith & Caldwell (1947) found, however, that DDT sprays killed many larvae and caused a sharp decline in damage. Weinman & Decker (1951) reported that field results with DDT and chlordane were variable and that more farmers reported success after using chlordane than after using DDT. Hibbs & Weaver (1951) reported fairly good control by DDT when they counted healthy, feeding larvae on corn at night with a flashlight, but when they caged larvae on treated plants and counted living and dead larvae after a 72-hour exposure, mediocre control resulted. Filmer & Ginsburg (1951) indicated generally poor results with DDT and toxaphene dusts on older armyworms. Their observations indicated that the worms had acquired sub-lethal doses as they lay on the ground, twisting and turning is an abnormal manner for several days. They reported mortality of the larger worms was low and several days after treatment many resumed feeding and started to pupate.

With reference to other insecticides, Bottger & Gertler (1949) reported that γBHC was two times as toxic as DDT to nearly full-grown armyworm larvae. Hibbs & Weaver (1951), using sprays, obtained good control with 0.5 lb. of parathion per acre, fair control with toxaphene, chlordane, and DDT, all at 1 lb. per acre, and poor control with lindane at 0.5 lb. Laboratory tests of Weinman & Decker (1951), based on LD-50's by contact, indicated an order of toxicity from most to least toxic as follows: parathion, dieldrin, aldrin, lindane, toxaphene, chlordane, and DDT.

INSECTICIDES AND METHODS OF EVALUATION.—Insecticides tested against the armyworm at various rates of application during the summers of 1953 and 1954 included toxaphene, endrin, dieldrin, parathion, DDT, BHC, chlordane, and methoxychlor. The rig devised for small plot applications on small grains consisted of a 3-gallon liquid-displacement pump sprayer attached to a 12-foot boom by means of a Neoprene hose. Six Teejet T-6 nozzles were spaced at 2-foot intervals along the boom. Two men, one at each end of the rig, were required to manipulate it during spraying. At the time of spraying, the nozzles were directed downward and the boom was moved through the plots, held at head-level of the wheat. At 40 p.s.i., the rate of walking was such that 25 gallons of spray was applied per acre. Wheat plots sprayed in 1953 were 90 feet long by 12 feet wide and were replicated twice. In 1954, plots 24 feet by 30 feet were sprayed along the edge of a field of meadow foxtail.

Several methods of taking data were attempted before two of them which proved to be most reliable were selected for use. One of the two methods employed consisted of picking up the first 25 larvae encountered, whether they were alive, moribund, or dead, in each of four locations in each plot. Data were thus accumulated on the per cent reduction of larve in each plot at various times after treatment.

The second method entailed sweeping with a net while the larvae were feeding on the foliage at night. Ten to 20 sweeps were made in each of three strips in each plot,

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Table 1.—Reduction of armyworms in tests conducted on wheat in 1953.

Insecticide	Pounds per Acre	Per Cent Reduction—Days After Treatment	
		3.5	5
		Collection Method	Sweeping Method
Endrin	0.1	64.0	94.6
	0.15	73.3	94.0
	0.2	89.5	98.3
Dieldrin	0.1	70.9	87.9
	0.15	67.4	83.0
	0.2	79.1	96.7
Toxaphene	2.0	69.8	89.3
Chlordane	1.5	66.3	89.0
Lindane	1.0	32.6	35.0
DDT	1.5	31.4	87.9
Methoxychlor	2.0	58.1	83.7

and the number of larvae per sweep was calculated. To partially eliminate variability in population densities, untreated areas bordering each plot were also swept and the per cent reduction of larvae as a result of treatment was calculated.

Samples of threshed wheat and straw taken from two test fields in 1953 were analyzed according to the Stepanov method of total chlorine analysis followed by the Volhard titration method to establish residue levels. To obtain an estimate of damage or the value of armyworm control, five 1-square-yard samples of grass were obtained from treated and untreated portions of a heavily infested meadow.

Results and Discussion.—Results obtained in the spring of 1953 (Table 1) show rather clearly the typical differences in the data obtained by the two methods of procedure. The same sort of test repeated in 1954 gave comparable and remarkably similar results (Table 2).

In both sets of experiments when toxaphene was used at 1 to 2 lb. per acre, dieldrin at 0.25 lb., and endrin at 0.15 to 0.2 lb., good control was indicated by both

Table 2.—Reduction of armyworms in tests conducted on meadow foxtail in 1954.

Insecticide	Pounds per Acre	Per Cent Reduction				
		Number of Days After Spraying				
		Collection Method		Sweeping Method		
		3	5	2	5	13
Endrin	0.1	71.2	83.8	77.9	96.0	25.9
	0.15	93.8	91.9	80.0	96.7	61.5
	0.2	93.8	94.6	88.8	97.9	68.3
Dieldrin	0.15	67.1	79.7	81.1	92.0	42.1
	0.2	69.2	91.9	82.0	90.2	54.5
	0.25	87.7	86.5	89.9	97.6	79.5
Toxaphene	1.0	81.5	87.8	88.7	92.6	74.5
	2.0	81.5	86.5	93.5	99.2	74.6
Parathion	0.25	11.6	0.0	45.5	79.3	Increase
	0.5	19.9	1.4	69.0	68.9	Increase
DDT	1.5	44.5	39.2	95.6	95.5	Increase
γBHC	1.0	19.9	5.4	80.8	67.4	2.6

Table 3.—Degree of reinfestation 13 days after treatment in plots of meadow foxtail 24 feet wide.

Insecticide	Pounds per Acre	Per Cent Reduction		
		Outer Edge of Plot	Middle of Plot	Average of Edge and Middle
Endrin	0.1	25.9	25.9	25.9
	0.15	57.1	65.9	61.5
	0.2	71.3	65.3	68.3
Dieldrin	0.15	62.2	22.0	42.1
	0.2	87.1	28.4	54.5
	0.25	92.1	66.9	79.5
Toxaphene	1.0	88.8	60.2	74.5
	2.0	94.0	55.2	74.6
Parathion	0.25	Increase	Increase	Increase
	0.5	Increase	Increase	Increase
DDT	1.5	Increase	Increase	Increase
γBHC	1.0	15.8	Increase	2.6

methods of acquiring data. Both methods also indicated that the use of parathion and BHC resulted in only poor to fair control. DDT at 1.5 lb. per acre, methoxychlor at 2 lb., and chlordane at 1.5 lb. gave poor armyworm control according to the method which involved collecting the worms from the ground surface, but the sweeping method indicated good control, especially in the case of DDT. It is easy to understand, therefore, why the use of these latter insecticides has in the past often resulted in conflicting reports. The results obtained with DDT and related materials could be explained in part at least by the findings of Filmer & Ginsburg (1951) who reported that larvae obtaining sub-lethal doses of DDT dust often resumed feeding and pupated several days later. The occurrence of this phenomenon seems probable when dusts are used because they are comparatively easily removed from the plant surfaces by wind and rain. Assuming that

Table 4.—Residues at harvest on wheat straw samples harvested July 9.

Insecticide	Pounds per Acre	Date of Treatment	Average p.p.m. Insecticide
Dieldrin	0.2	6/6	1.3
	0.2	6/12	3.7
Endrin	0.2	6/6	0.7
	0.2	6/12	7.4
Toxaphene	2.0	6/6	3.6
	2.0	6/12	12.5
Chlordane	1.5	6/6	1.5
	1.5	6/12	10.3
DDT	1.5	6/6	8.8
	1.5	6/12	45.7
Check	—	6/6	0.0
	—	6/12	0.0

Table 5.—Yields in grams per square yard of treated versus untreated meadow foxtail (1954).[a]

Replicate	Weight in Grams			Per Cent Gain Over Check
	Treated	Untreated	Difference	
1	936	426	510	119.7
2	851	369	482	130.6
3	738	341	397	116.4
4	709	298	411	137.9
5	709	213	496	232.9
Average	788.6	329.4	459.2	139.4

[a] Per cent reduction by larval feeding (wet wt.) = 58.2.

a spray deposit of DDT would be less easily removed than a dust deposit, and considering the residual properties of DDT, one might suspect that if sprays were used any larvae which recuperated from the first sublethal dose and attempted to feed again would be apt to find themselves confronted with the same problem all over again. Our data fail to show conclusively that this is or is not the case, but indications are that DDT treatments lose effectiveness rapidly. The best indication of what may eventually happen is shown in table 2 where sweeps were made 13 days after treatment.

Of more than casual interest are the data taken 13 days after treatment as shown in table 3. Bearing in mind that the treated plots were only 24 feet wide, that all bordered untreated meadow on one side and that, as early as a week after treatment, practically all of the leaves had been devoured in the untreated check areas while substantial foliage remained and growth was continuing in the treated plots, the tendency for larvae to migrate from untreated to treated areas must have been very great. We would therefore expect the population in plots receiving ineffective or short-lived treatment to exceed those encountered in the checks. As a matter of fact this did occur in the DDT, parathion, and some BHC plots. It seems remarkable that almost 2 weeks after treatment, endrin, dieldrin, and toxaphene were still causing good reductions of larvae in the outer third of the plots (the part furthest away from the untreated areas) and even a fair amount of reduction in the middle of the plots. That this was the case may suggest that barrier-type spray applications might be used to protect uninfested young corn bordering infested small grain or pasture without the necessity of having to spray both fields in their entirety to protect the corn from damage.

Chemical analyses for residues were conducted both on threshed wheat and straw taken from the test wheat fields at the time of harvest in 1953. The amounts of residue found on the straw varied from a high of DDT to a low of dieldrin and endrin as shown in table 4. This is reasonable since approximately eight times as much DDT was applied initially as was endrin or dieldrin and since DDT normally has the longest residual life of the three. No detectable residues of any of the insecticides could be found on the threshed wheat.

As shown in table 5, the treated area produced almost 2½ times as much cut grass as did the check areas or that without control. There was a 58 per cent reduction in foliage production as a result of larval feeding. Furthermore, most of the plant weight in the checks was made up of stems which the larvae did not find attractive. Therefore, had the data been taken on the basis of leaf weight or quality hay rather than on the combined weights of leaves and straw, the results would have been all the more striking.

SUMMARY.—Of the insecticides tested in the field, toxaphene at 1 to 2 lb. per acre, dieldrin at 0.25 lb. and endrin at 0.15 to 0.25 lb. all caused high reductions in armyworm populations. Some of the other insecticides tested, particularly DDT at 1.5 lb. per acre, while giving poor kills did result in a reduction in feeding as indicated by sweeping the foliage at night. Just how long DDT will keep larvae too sick to feed is unknown since rapid increases in the prevalence of parasites and diseases in all of our test fields prevented taking data for long periods of time after treatment. Residue analyses on wheat, straw and grain samples taken just before harvest indicated a high with DDT to a low with endrin and dieldrin present on the straw with all the other insecticides falling somewhere in between. Any residue possibly present on the threshed grain itself was below the sensitivity of the method of analysis.

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Damage to Our Forests Caused by the Gypsy Moth in 1953[1]

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In the course of gypsy moth (*Porthetria dispar* (L.) activities during 1952 by the Bureau of Entomology and Plant Quarantine, both in regular work and in connection with a special appraisal program, many reports of unusual increases in egg-mass populations were received from the field men. Most of the workers predicted extensive defoliation in the late spring and early summer of 1953 if large-scale spraying operations were not undertaken and if conditions were favorable for hatching and larval development. These predictions proved well founded, as it has been estimated that nearly a million and a half acres were defoliated. This estimate is based on surveys conducted by the Bureau and the Massachusetts Department of Natural Resources.

The defoliation conditions found in the infested region are shown in table 1.

Build-up in gypsy moth population in the infested region as a whole was first noted in the summer of 1952, when defoliation increased to 293,052 acres from 21,314 acres in 1951. The tremendous increase to nearly 1½ million acres in 1953 is without precedent.

In Maine serious defoliation was confined to the southeastern part of the State in sections of Oxford, Androscoggin, Cumberland, Sagadahoc, York, Lincoln, Knox, Kennebec, Hancock, and Waldo counties, with isolated spots in Penobscot, Somerset, and Washington counties.

In New Hampshire, concentrations of heavy defoliation were located in Grafton, Carroll, Belknap, and Strafford counties in the east-central part of the State, with scattered acreages in Merrimack, Rockingham, and Hillsboro counties in the southeastern part. A marked concentration of defoliation occurred in the Connecticut River Valley in Grafton, Sullivan, and Cheshire counties.

In Vermont, defoliation was general in the Connecticut River Valley in Orange, Windsor, and Windham counties, and in Addison, Rutland, and Bennington counties in the western part of the State.

In Massachusetts, extensive areas in the Connecticut River Valley in Franklin, Hampshire, and Hampden counties were seriously defoliated, as well as a section in west-central Worcester County and in scattered areas in Norfolk, Berkshire, Essex, and Middlesex counties.

In Connecticut there was widespread defoliation in Litchfield and Hartford counties and some defoliation in two towns at the north-central tip of New Haven County and the northern portion of Middlesex County.

In New York, defoliation in the 75 to 100 per cent category was reported in two towns in Washington County, with acreages of less damge in other towns in that county and in Rensselaer County.

CYCLICAL RECURRENCE OF DEFOLIATION.—Records for the last 25 years reveal a decided cyclical recurrence in peaks of defoliation at about 8-year intervals, with minor crests preceding the peaks. For example, in 1929 a peak of 551,133 acres was recorded; in 1937, 608,760 acres; in 1945, 821,487 acres; and in 1953 a new high of 1,487,077 acres.

The causes for these cyclical peaks are obscure, but are thought to be related, in some degree at least, to climatic conditions and control by natural enemies of this pest. Studies are being undertaken to determine the factors influencing these population build-ups, in the hope that more economical and effective control programs can be set up.

Table 1.—Estimated acreages of defoliation in the region infested with the gypsy moth, 1953.

STATE	100%	LESS THAN 75%	TOTAL
Connecticut	4,605	51,610	56,215
Maine	91,237	83,762	174,999
Massachusetts	371,324	546,672	917,996
New Hampshire	51,440	157,895	209,335
New York	10	7,735	7,745
Rhode Island	—	—	—
Vermont	12,287	108,500	120,787
Total	530,903	956,174	1,487,077

DAMAGE FROM DEFOLIATION.—Over the years heavy mortality and retardation of growth of trees has occurred on large areas in New England as a result of defoliation by the gypsy moth. In some localities from 3 to 50 per cent of the oaks have been killed. Research has determined that retardation in growth is in direct proportion to the percentage of defoliation. Mortality of young white pines has been substantial in many defoliated areas where this tree species was present in mixed stands.

In connection with the 1952 appraisal program conducted by the Bureau, a study was made to evaluate the damage resulting from gypsy moth defoliation. In the absence of long-range studies, the consulting forester engaged for this phase of the program encountered the same difficulties experienced by others in placing a monetary value on losses resulting from mortality and retarded growth.

It is of interest to report at this time that a study has recently been initiated, in which permanent sample plots are being established in susceptible growth in typical areas distributed throughout the infested region. From these plots it is hoped that it will be possible to measure these losses more definitely, particularly in mixed stands where damage to softwoods is likely to occur.

Basic data available from previous research, correlated with the results of investigations conducted in 84 sample areas in 1952, were helpful to the consulting forester in arriving at loss figures. There has been increasing evidence that complete defoliation during two successive seasons (or in some instances after one complete stripping) is fatal to softwoods, notably hemlock. However, in the absence of detailed long-term records, it has not yet been possible to arrive at reliable figures on losses to softwood species.

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Although damage due to mortality and retarded growth is extremely important, intangible losses resulting from deterioration of forest stands and the general harmful effect on the future productive capacity of defoliated forests are paramount. The consulting forester pointed out that it is not possible even to guess at the loss in dollars and cents resulting from the nuisance effect of this pest in areas of high aesthetic value which are so vital to the recreational industry of the northeast. However, some measure of this nuisance can be gained from the fact that states, counties, municipalities, and property owners have willingly expended nearly a million dollars yearly for the last 20 years in an effort to prevent defoliation in residential and scenic properties.

TORNADO SPREAD.—The serious situation within the gypsy moth infested region in 1953 was complicated by the occurrence on June 9 of three devastating tornadoes, two in Massachusetts and one in New Hampshire.

The first and most destructive originated in its ground phase at 4:25 P.M. in Petersham, Worcester County, Massachusetts, near the Quabbin Reservoir and the Harvard Forest. It swept through central Worcester County, leaving death and utter ruin in its path through eight towns to Southboro, before its fury was exhausted. During its 46-mile course the swath ranged in width from 500 yards to 1 mile.

The second storm hit Exeter, New Hampshire, at 5:20 P.M., but was of short duration on a track 1.5 miles long. Damage was minor.

The third air disturbance, which occurred in Massachusetts, first struck ground at 5:30 P.M. in Sutton, Worcester County, traveled through five towns in that county, five towns in Norfolk County, and ended in Mansfield in Bristol County. This storm, in its track of 29 miles with a maximum width of 0.7 miles, was just as violent as the Petersham-Southboro tornado, but did not pass through so many densely populated areas.

One of the most extraordinary features of the first Massachusetts tornado was the vast amount of debris showered down on Boston and South Shore communities, 25 to 30 miles away from the end of the track in Southboro and 40 to 45 miles from Worcester, from which most of the debris originated. Shingles, clapboards, siding, roofing paper, sales slips, clothing such as neckties (with price tag attached), branches, and miscellaneous material, carried by the violent upper air currents, dropped from the sky to the bewilderment of the local populace.

A 1953 gypsy moth defoliation map of New England shows clearly that the Petersham-Southboro storm originated in areas of heavy defoliation near the Quabbin Reservoir in Petersham and continued through areas of light defoliation in Barre. Over the remainder of the track the storm passed through areas of general infestation.

At the time of the tornadoes, most of the gypsy moth larvae in the areas through which the storms passed were in the third instar. Meteorologists are of the opinion that millions of these larvae could have been carried aloft and dispersed with other debris to distant points to the southeast. The significance of such a situation is that larvae may have been deposited rather generally in many towns in Plymouth and Barnstable counties, where successful county spraying operations on an exterminative basis were carried on in 1949 and 1950. The results of these spraying operations had been encouraging and, although points of persisting infestation were found, it was anticipated that through trapping and spraying of these small outbreaks it would be possible at least to hold the insect in check and prevent defoliation at a small annual expense.

In the path of the third storm (Sutton-Mansfield) there were areas of general infestation, but no serious defoliation in the first section of its course. However, in Bellingham and Wrentham the storm passed through areas of heavy defoliation before it ended in Mansfield.

The debris carried on the upper air currents was attributed largely to the severity of the storm in the heavily populated area in Worcester. Therefore, it seems likely that gypsy moth larvae were carried from Bellingham and Wrentham to towns in Plymouth County and possibly Barnstable County, to complete their life cycle. However, the debris (including gypsy moth larvae) might have been deposited in the Atlantic Ocean.

There are certain facts associated with tornadic disturbances that may have an important bearing on the survival of the larvae. Meteorologists point out that the currents of air in the storms ascended to nearly 60,000 feet, where the temperature is below freezing. Engineers of power companies reported estimates of wind velocities up to 350 miles an hour on the periphery of these storms. Some entomologists express doubt, therefore, that many larvae could have withstood these severe meteorological influences.

On the other hand, in gypsy moth trapping operations during July and August male moths were caught at numerous points in Plymouth and Barnstable counties. Some entomologists are of the opinion that these captures represent an adult population which developed from larvae dispersed by the tornadoes. Others contend that these catches are consistent with the phenomenal build-up by the insect in New England in 1952 and especially in 1953, when nearly 1½ million acres were defoliated. Evidence will never be available to provide a definite answer to this debatable situation, but the dispersal of gypsy moth larvae by the tornadoes of 1953 is within the realm of possibility.

CONCLUSION.—In conclusion it may be said that the picture in the area infested with the gypsy moth is not bright. The Federal Government and its cooperators are dedicated to prevent spread of the insect outside the generally infested area as a protection to the more than 100 million acres of valuable oak forests of the Appalachian region, the South and Middle West. The Federal Government will provide, wherever possible, technical assistance to the States in the northeastern region and help to plan and carry out measures agreed upon to prevent damage to forest, shade, and fruit tree resources of the region.

The Effects of Certain Insecticides on the Cholinesterase of the American Cockroach[1,2]

J. B. Hartley[3] and A. W. A. Brown,[4] *University of Western Ontario, London, Canada*

It is generally accepted that the inhibition of cholinesterase is an important factor in the toxicity of the organic phosphate insecticides to insects; this view has been strengthened by the recent proof of the presence of acetylcholine in *Calliphora* and *Lucilia* (Lewis 1953). Relatively little is known, however, about the effects of the chlorinated hydrocarbons on this enzyme. Although DDT and many related compounds do affect nervous transmission, there have been few indications that these are anticholinesterases.

Tobias *et al.* (1946) reported that the amount of free acetylcholine doubled in the central nervous systems of *Periplaneta americana* and *Musca domestica* during the late prostrate phase of DDT poisoning. However these authors, as well as Richards & Cutkomp (1945), were unable to demonstrate the inhibition of cholinesterase in insects by DDT either *in vivo* or *in vitro*. An apparent anomaly was observed by Stegwee (1952), who found cholinesterase activity had almost entirely disappeared from the central nervous system of *P. americana* when poisoned to paralysis by contact with a DDT dust, but not when injected intra-abdominally with an oil solution of the insecticide. One can infer from Stegwee's report that the dust was a technical formulation containing 5 per cent DDT (Shell *Arkotine*), which may have contained an anticholinesterase impurity, whereas the injected solution was composed of pure DDT in rapeseed oil.

In view of the above contradictory reports, the present investigation was designed to screen the chlorinated hydrocarbon insecticides for their effect on insect cholinesterase, using *in vitro* methods which allow strong inhibition of the enzyme by certain organic phosphates such as TEPP. The botanicals and several miscellaneous insecticides were also examined.

Burgen (1949) and Roan & Maeda (1953) exphasized the danger of estimating the *in vivo* inhibition of cholinesterase from data obtained *in vitro* due to the competition between substrate and inhibitor for the active centres in the enzyme molecule. Burgen postulated that the effectiveness of an irreversible inhibitor, such as TEPP, is overestimated by the usual *in vitro* method in which the substrate is added to the enzyme-inhibitor complex. In contrast, the action of a reversible inhibitor (e.g. eserine) may be underestimated by this method, in which the concentration of substrate is higher than that in living tissue. In the present series of tests, therefore, any negative influence exerted against inhibition by the addition of substrate prior to the inhibitor was detected by the method which was first employed. All the insecticides listed in table 1 were tested by method 1 at a temperature of 37.0±0.2° C. Those compounds that exhibited effects on cholinesterase, as well as other representative insecticides, were retested at 27.0±0.2° C. by a second method in which the substrate was added to the enzyme brei after the insecticide.

Methods and Materials.—Cholinesterase activity was measured manometrically, utilizing 15-ml. flasks and a rectangular, dual-shaker Warburg-Barcroft apparatus. All reagents were prepared immediately before each test, and glass-redistilled water was employed throughout.

The enzyme was prepared from brain tissue by the homogenization of entire heads of adult *P. americana*, 6 males and 6 females, in 26 ml. of cold buffer solution. The latter contained 0.025 M sodium bicarbonate, 0.04 M magnesium chloride, and 0.15 M sodium chloride; it was prepared from stock solutions of the chemicals. The pH of the buffer varied between 7.65 and 7.70, depending upon the age of the bicarbonate solution. The homogenate was centrifuged to remove the coarser particles of tissue. The substrate was acetylcholine bromide dissolved in water to give a final concentration in the flasks of 0.007 M.

The insecticides were obtained in as pure a form as possible from the manufacturer (see Table 1). The chlorinated hydrocarbons and dinitro compounds, being solids, were then recrystallized from ethanol before being tested. The purified pyrethrins were obtained as a solution in *n*-hexane, and consisted of 30 per cent of cinerins I and II in equal quantities, and 70 per cent of pyrethrins I and II in equal quantities. The Lethane thiocyanates were obtained in purified form from the manufacturer, who distilled them from the technical product which contains 50 per cent kerosene. The nomenclature of the chemical compounds involved with these insecticides is listed in a previous paper (Morrison & Brown 1954).

The insecticides were initially dissolved in glass-distilled acetone and *Triton X-100* and then diluted with water. The aqueous solutions contained 10 per cent acetone, 0.5 per cent *Triton X-100*, and insecticide at a level calculated to give the desired concentration after the final dilution in the flasks. The solvent control solutions were identical to the insecticide solutions except for the absence of insecticide.

Method 1—Substrate added to the enzyme prior to the insecticide.—All the insecticides were tested by this method at a final concentration of 10^{-3} M. Those compounds that exhibited effects were retested at a lower concentration. Eight manometer flasks were used in each test, consisting of duplicate sets of thermobarometers, enzyme controls, insecticide controls, and insecticide test flasks. Aliquots of the reagents were pipetted into the flasks so that the contents of each were as follows:

Thermobarometric flasks
moat: 3.0 ml. water

[1] *Periplanata americana* (L.).

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[4] The authors are indebted to Dr. E. Y. Spencer, Science Service Laboratory, London, Canada, for a purified sample of schradan; to Dr. Murray S. Blum, University of Illinois, for a specially purified sample of pyrethrins to the Rohm & Haas Research Laboratories, Philadelphia, for specially distilled samples of the active compounds in *Lethane 60* and *Lethane 384*; and to Dr. B. N. Smallman, Science Service Laboratory, London, for general assistance with chemical and biological materials.

Table 1.—Effect of insecticides on cholinesterase of *Periplaneta americana* (L.).[a]

Insecticide	Purity	Source	Molar Concentration	Volume of CO_2 Evolved, Cu. Mm.			
				Method 1		Method 2	
				Control	Experimental	Control	Experimental
Chlorinated Hydrocarbons							
DDT	Recrystallized	Science Serv. Lab., London	10^{-3}	139	138	104	100
DDD	Recrystallized	Rohm & Haas Co.	10^{-3}	139	136		
Methoxychlor	Recrystallized	Du Pont Expt. Station	10^{-3}	134	139		
BHC	Technical	Canadian Industries Ltd.	10^{-3}	114	128		
Lindane	Recrystallized	Exp. Station, Suffield	10^{-3}	114	122	104	105
α-Chlordane	Recrystallized	Julius Hyman & Co.	10^{-3}	130	139		
β-Chlordane	Recrystallized	Julius Hyman & Co.	10^{-3}	134	127		
Heptachlor	Recrystallized	Julius Hyman & Co.	10^{-3}	134	128	96	97
Aldrin	Recrystallized	Julius Hyman & Co.	10^{-3}	128	131		
Isodrin	Recrystallized	Julius Hyman & Co.	10^{-3}	137	143		
Dieldrin	Recrystallized	Julius Hyman & Co.	10^{-3}	128	116	96	99
Endrin	Recrystallized	Julius Hyman & Co.	10^{-3}	137	149		
Toxaphene	Recrystallized	Hercules Powder Co.	10^{-3}	166	153	83	80
Dinitro Compounds							
DNOC	Recrystallized	Standard Agric. Chemicals	10^{-3}	126	132[b]	83	83
DNOCHP	Recrystallized	University of Toronto	10^{-3}	126	115[b]		
DNOSBP	Recrystallized	Dow Chemical Co.	10^{-3}	135	134[b]		
Organic Phosphorus Compounds							
TEPP	40 per cent, as *Nifos-T*	Monsanto Chemical Co.	10^{-3}	124	4[b]	77	2[b]
			10^{-5}	129	9		
Parathion	Purified	American Cyanamid Co.	10^{-3}	138	110	77	8
Malathion	Purified	American Cyanamid Co.	10^{-3}	124	85	84	0
Schradan	Purified	Science Serv. Lab., London	10^{-3}	128	127		
Diazinon	90 per cent pure	Geigy Co.	10^{-3}	138	11	84	0
			10^{-5}	129	77		
EPN	Pract. pure	Du Pont Expt. Station	10^{-3}	138	143		
Insecticides of Botanical Nature							
Nicotine	Eastman grade	Eastman Kodak Co.	10^{-3}	139	96	91	58
			10^{-5}	129	134		
Pyrethrins	Purified	University of Illinois	10^{-3}	117	119		
Allethrin	Purified	U. S. Industrial Chem.	10^{-3}	129	131		
Rotenone	Recrystallized	University of Toronto	10^{-3}	129	125		
Sabadilla	Ether extract	Merck & Co.	"10^{-3}"	133	139		
Ryania	Ether extract	McConnon & Co.	"10^{-3}"	166	164		
Miscellaneous Organic Compounds							
Phenothiazine	Pract. grade	Eastman Kodak Co.	10^{-3}	134	136		
Lethane 384	Redistilled	Rohm & Haas Co.	10^{-3}	135	135		
Lethane 60	Redistilled	Rohm & Haas Co.	10^{-2}	135	153		
			10^{-3}	117	162	89	124
			10^{-4}	135	140		
			10^{-5}	123	122		
	Technical	Rohm & Haas Co.	10^{-3}	139	154		
Pyrolan	Pract. pure	Geigy Co.	10^{-3}	123	23	89	4
			10^{-5}	138	124		

[a] Comparison of presence (Exp't'l) and absence (Control) of insecticide, expressed in terms of the evolution of CO_2 for the first 80 minutes after the addition of insecticide in Method I and of substrate in Method II.
[b] Corrected by subtracting the volume of CO_2 evolved from the bicarbonate buffer by the acidity of the insecticide.

Enzyme control flasks
moat: 2.6 ml. enzyme brei
0.3 ml. acetylcholine bromide
side-arm: 0.1 ml. insecticide solvent
Insecticide control flasks
moat: 2.6 ml. buffer
0.3 ml. acetylcholine bromide
side-arm: 0.1 ml. insecticide
Insecticide test flasks
moat: 2.6 ml. enzyme brei
0.3 ml. acetylcholine bromide
side-arm: 0.1 ml. insecticide

The atmosphere of the flasks and closed portions of the manometers was replaced by a mixture of 95 per cent nitrogen and 5 per cent carbon dioxide, according to the procedure described by Umbreit *et al.* (1945). Twenty minutes after the addition of substrate to the enzyme the manometers were placed in the Warburg apparatus and equilibrated for 15 minutes with the temperature of 37° C. Gassing was then repeated and followed again by temperature equilibration. The stop-cocks were closed 55 minutes after the addition of substrate to the enzyme. Manometer readings were taken at 10-minute intervals

during the next 2 hours. After normal enzyme activity had been measured for 40 minutes, the contents of the side-arms were tipped into the moats of the flasks.

The pH of the flask contents was determined at the termination of each test in the case of nine representative compounds, and showed the following averages and ranges of values: thermobarometers 5.2 (5.1–5.5), enzyme controls 7.0 (6.9–7.3), insecticide controls 7.2 (7.1–7.3), and insecticide tests 7.0 (6.9–7.1). The absence of the buffering effect of the enzyme brei accounts for the high pH of the insecticide controls.

The insecticide controls were designed especially to measure the release of carbon dioxide from the buffer by such acidogenic insecticides as the dinitro compounds and TEPP. They were included in the tests on the organic phosphate, dinitro compounds, organic thiocyanates, botanicals, and certain of the chlorinated hydrocarbons.

Method 2—Insecticide added to the enzyme prior to the substrate.—A number of insecticides were re-assessed at 10^{-3} M in a second series of tests. In the second method the substrate was tipped from the side-arms into the enzyme-insecticide mixture present in the test flasks; the tests were conducted at a temperature of 27° C. in the water bath. The thermobarometers, enzyme controls, insecticide controls, and insecticide tests were duplicated as before. The flasks were prepared at room temperature. The replacement of the flask atmospheres and the temperature equilibration in the Warburg apparatus, both procedures repeated once, were conducted as in method 1. The stop-cocks were closed after 60 minutes, and the substrate was tipped into the moats after the insecticide had been incubated with the enzyme for 90 minutes. Manometer readings were then taken at 10-minute intervals for 80 minutes.

The pH of the contents of each flask was measured after every test. The average values corresponded generally with those obtained earlier: Thermobarometers 5.2 (5.1–5.5), enzyme controls 7.05 (7.0–7.1), insecticide controls 7.2 (7.0–7.3). There appears to be a significant difference, however, between the values given by the insecticide tests showing no inhibition and those in which inhibition was observed. The average pH was 7.0, (6.9–7.1) for the negative tests, and 7.2, (7.1–7.2) for the tests which were positive for inhibition. In the latter tests the anticholinesterase effect reduced the amount of acetic acid freed from the substrate, and thus the final pH would be higher than that in the negative tests.

RESULTS.—The amounts of carbon dioxide produced by the insect cholinesterase for a period of 80 minutes following the addition of the insecticide (Method 1) or of the substrate (Method 2) are tabulated in table 1. Each value is the average of the duplicates, the variation between which averaged 6.3 per cent, with a maximum variation of 13.7 per cent. In the case of acidogenic compounds (DNOC, DNCHP, DNBP, and TEPP) the volume of gas evolved in the test flasks was corrected by subtracting the volume produced in the corresponding insecticide controls.

None of the chlorinated hydrocarbons effected any inhibition, since in no instance did the experimental figures differ from the controls by more than 11 per cent. Of the 32 insecticides tested, only 6 exerted any inhibition on cholinesterase at the concentrations employed. These were TEPP, malathion, parathion, Diazinon, pyrolan and nicotine. Their effects on the normal enzymatic hydrolysis, by method 1, are shown graphically in figures 1 to 3. The inhibition exerted by the sample of parathion was only slight at 10^{-3} M, and nicotine did not maintain its inhibition when tested at 10^{-5} M concentration.

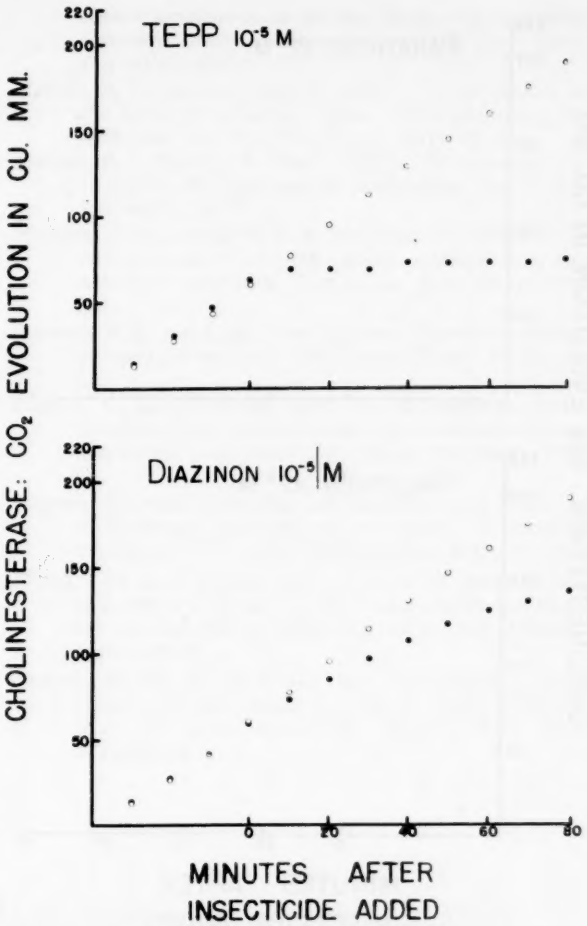

FIG. 1.—The effect of TEPP and Diazinon on the cholinesterase of *Periplaneta americana*. ● Experimental. ○ Control.

At 10^{-3} M concentation, β-thiocyanoethyl laurate increased the gas evolution by 38 per cent in method 1 and 39 per cent in method 2. A 10^{-3} M concentration of the same compound formulated as a 50 per cent solution in petroleum distillate (*Lethane 60*) increased the CO_2 production by 11 per cent in method 1. Since a similar increase in gas evolution was obtained if the substrate was omitted from the digest, it is indicated that the additional gas was released by a reaction between β-thiocyanoethyl laurate and the tissue brei. An increase was also effected at a concentration of 10^{-2} M, but not at 10^{-4} and 10^{-5} M; it was not given by free lauric acid.

DISCUSSION.—The ineffectiveness of DDT at 10^{-3} M on the cholinesterase of *P. americana* corroborates the negative results obtained *in vitro* by Richards & Cutkomp

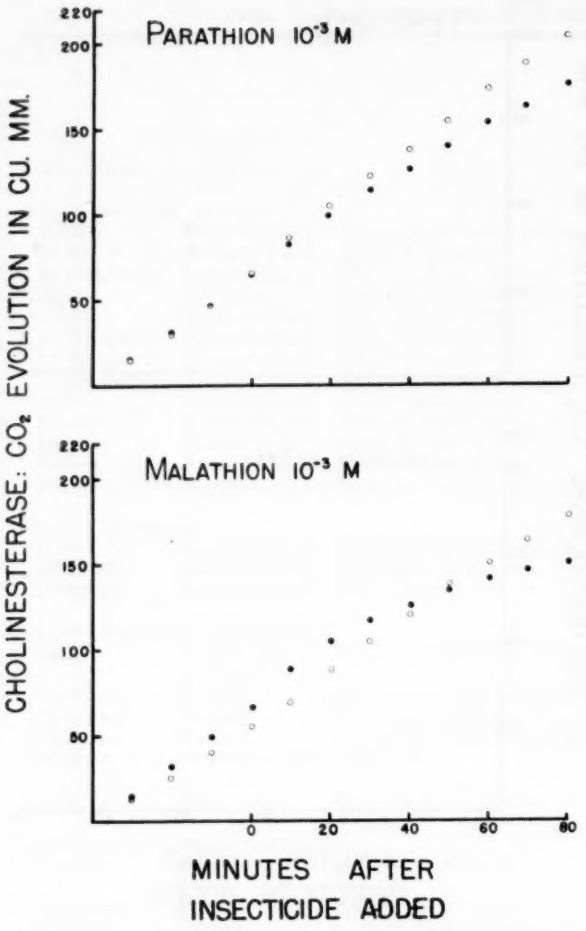

FIG. 2.—The effect of parathion and malathion on the cholinesterase of *Periplaneta americana*. ● Experimental. ○ Control.

(1945) and *in vivo* by Tobias *et al.* (1946). The present investigation also confirms an earlier report (Richards & Cutkomp 1945) that B-butoxy-B-thiocyanodiethyl ether (the active principle of *Lethane 384*), pyrethrins, and rotenone are not anticholinesterases *in vitro*.

Of the results with the organic phosphates, the strong inhibition of insect cholinesterase by Diazinon is worthy of note. Previously its anticholinesterase effect has been reported for human erythrocytes and plasma (Gasser 1953). The inhibition by TEPP is not noteworthy, but is of comparative value. The inhibition by purified parathion and malathion is attributable to its isomerization on aging (Metcalf & March 1953b), since evidently biological oxidation and autoxidation do not occur *in vitro* (Metcalf & March 1953a). The lack of inhibition by schradan is in agreement with previous findings (DuBois *et al.* 1950). The lack of inhibition by EPN runs counter to the findings of Metcalf & March (1950) on the honey bee and of Roan & Meada (1953) on the oriental fuit fly, but it may be related to the freshness and purity of the sample, which was described by the manufacturer as "pure for all practical purposes" and was tested 2 days after being received.

The anticholinesterase effect of Pyrolan, found here with *Periplaneta americana*, has been previously reported by Roan & Maeda (1953) with *Dacus dorsalis*. They observed that Pyrolan at 2.0×10^{-6} M caused 93 per cent inhibition when added before the substrate at 25° C., and 64 per cent when added after the substrate at 37° C. The corresponding inhibition by Pyrolan at 1×10^{-3} M in this investigation was 92 per cent at 27° C., and 81 per cent at 37° C. The fact that the threshold concentration of nicotine required to inhibit cholinesterase lay between 10^{-5} M and 10^{-3} M suggests that its action is non-specific. Richards & Cutkomp (1945) also failed to find any effect on cholinesterase by a low concentration of nicotine.

An examination of table 1 reveals that each of the inhibitor compounds effected a greater inhibition by method 2 than by method 1. This difference is particularly marked in the case of parathion and malathion. Evidently the conditions in method 1, in which substrate is added before the insecticide, allow the formation of an enzyme-substrate complex which reduces the effect of inhibitor subsequently added. The difference is not shown in the case of TEPP, since the concentrations tested were far in excess of the IN_{50} of this compound and thus sufficient to effect virutally complete inhibition by both methods.

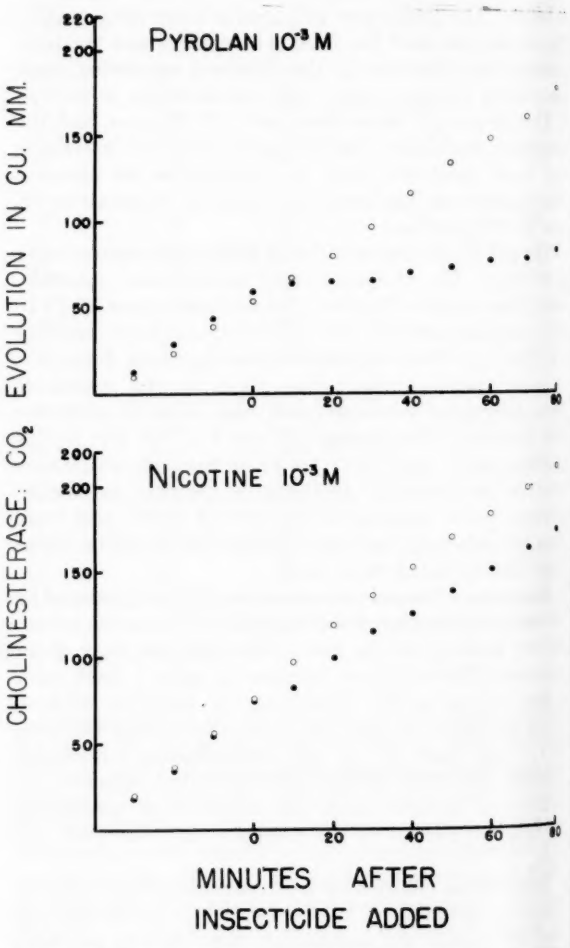

FIG. 3.—The effect of Pyrolan and nicotine on the cholinesterase of *Periplaneta americana*. ● Experimental. ○ Control.

Summary.—A total of 32 insecticidal compounds were tested by two manometric methods for their effect *in vitro* on cholinesterase from the head of the American cockroach. The 13 chlorinated hydrocarbons tested, including DDT, lindane and the chlordane compounds, had no significant effect on this enzyme. Of the six organic phosphates tested, schradan and EPN had no effect, but Diazinon, TEPP, and purified but aged samples of parathion and malathion were inhibitory. Pyrolan proved to be an anticholinesterase. Nicotine was a partial inhibitor at 10^{-3} M, but not at 10^{-5} M concentration. The active principles of *Lethane 60*, β-thiocyanoethyl laurate, gave a false appearance of increasing cholinesterase activity; but the increased gas evolution did not arise from the acetylcholine substrate.

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Laboratory Comparison of Some Insecticides as Larvicides against Nonresistant House Flies[1]

Robert H. McCauley, Jr., Mary M. Grainger, Donald A. Lindquist, and Richard W. Fay

This study compares the effectiveness of certain toxicants as house fly larvicides when sprayed on the surface of undisturbed breeding medium containing various immature stages of house flies, an application technique most suitable for field use. All formulations were tested as emulsions prepared by adding water in various proportions to concentrates of different toxicants. For convenient and practical comparisons of the toxicants, only two factors were varied: (1) the amount of concentrate used in each emulsion and (2) the age of the house fly culture treated.

The seven insecticides tested were DDT, methoxychlor, BHC (95 per cent gamma isomer content), toxaphene, chlordane, aldrin, and dieldrin. The susceptibility of newly hatched, small and large larvae and of pupae to insecticide treatment of the medium were studied for each insecticide.

Procedure.—In preparing a house fly culture, 1000 gm. CSMA[2] rearing medium was placed in each covered 6-inch-diameter, 9-inch-high battery jar for 1 day. Then 25 mg. of newly hatched larvae was placed on the medium in each jar. Four time intervals between inoculation of the medium with larvae and its treatment with insecticide were used as follows: "−1" designates treatment 1 day before the fly larvae were introduced and "1," "3," or "5" designates the treatment at 1, 3, or 5 days after the larvae were introduced. In practice, therefore, the susceptibility of newly hatched, small and large larvae and of pupae were compared.

Spray was applied on the surface of a culture with a conventional nasal atomizer using 10 p.s.i. air pressure. The spray was applied evenly and not mixed or stirred into the culture in any way. Xylene concentrates containing 25 per cent insecticide[3] and 2 per cent Triton X-100 were emulsified with water so that 5 ml. volumes applied on the 0.2 sq. ft. area of the culture gave the desired dosage. Dosages of 1250, 750, 250, 125, 62.5, 25, 12.5, 6.25 and 2.5 mg. of insecticide per sq. ft. were used. Cul-

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia. Accepted for publication Dec. 16, 1954.

[2] Chemical Specialties Manufacturers Association Standard Fly Rearing Medium prepared by the Ralston Purina Co., St. Louis, Mo. Trade names are used as a means of identifying products their use does not constitute endorsement by the U. S. Public Health Service.

[3] Tests made with amounts of xylene equal to those used in applying insecticides at 1250 mg. per sq. ft. when applied to 1-day-old cultures had no measurable deleterious effect on the insects.

Table 1.—The per cent reductions as larvae, pupae, and adults of house flies after 5 ml. spray applications of DDT emulsions on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	−1	34	65	0	99
	1	46	53	0	99
	3	14	81	2	97
750	−1	15	85	0	100
	1	45	54	0	99
	3	18	80	1	99
	5	8	1	0	9
250	−1	10	78	8	96
	1	17	82	0	99
	3	12	82	4	98
	5	16	1	0	17
125[b]	−1	20	37	22	79
	1	21	45	18	84
	3	7	28	21	56
62.5[b]	−1	13	10	20	33
	1	23	17	19	59
	3	7	9	12	28
25[b]	−1	18	3	2	23
	1	7	7	4	18
	3	2	2	6	10

[a] Results are the averages of six replicates each.
[b] Dosage gave no mortality when applied to 5-day-old cultures.

tures were left undisturbed for 7 days following larval introduction so that pupation might be completed.

To prevent supervenient egg deposition, culture jars were capped with unbleached muslin secured by large rubber bands. These covers were used once only and the culture jars were washed in xylene after each test to avoid insecticide contamination. With the volatile insecticides test jars were placed on partitioned shelves in a special hood to avoid any insecticide fumigant contamination.

The dry upper portion of the culture media which contained the pupae was wet thoroughly with water in a 12 × 12 mesh-per-inch sieve so that the soaked medium sank when placed in a dish of water and allowed the pupae to float free. The pupae were collected, counted, dried on paper towelling and placed in an emergence cage. The flies which emerged were allowed to die and counts were made (1) of normal adults and (2) of defective or incompletely emerged adults.

In each 10 cultures, one was designated as a check, the others were divided into three groups of three replicates each, all treated at the same age but with three dosages of an insecticide. Each triplicate series for a given set of conditions was replicated on 2 days with different check cultures. The average per cent reduction values are each derived from six treated cultures and two untreated cultures. Untreated cultures averaged about 300 pupae and tests were discarded if low production occurred in the untreated cultures. In all, 573 series of three similar test cultures were used in this study.

Insecticide effectiveness was based on three values: (1) the pupae produced, (2) the total adult flies, and (3) the normal or nondefective flies. Using these data, the per cent reductions as larvae, pupae and defective adults were obtained by the following formulae:

(1) Per cent reduction as larvae

$$= \frac{(\text{Check pupae} - \text{test pupae})(100)}{(\text{check pupae})} = A.$$

(2) Per cent reduction as pupae

$$= \frac{(\text{Total check adults} - \text{total test adults})(100)}{(\text{total check adults})} - A = B.$$

(3) Per cent reduction as adults

$$= \frac{(\text{Check normal adults} - \text{test normal adults})(100)}{(\text{check normal adults})} - A - B = C.$$

(4) Total per cent reduction $= A + B + C$.

Results.—*DDT.*—As a standard for comparison, the results of surface applications of 25 to 1250 mg. of DDT per sq. ft. to cultures of various ages are shown in table 1. Applications made to cultures of partially grown larvae (−1 to 3 days) at 250 mg. of DDT per sq. ft. gave good mortalities but applications of 125 mg. of DDT per sq. ft. represent a break in effectiveness of the insecticide. Dosages as high as 1250 mg. of DDT per sq. ft. were ineffective on 5-day-old cultures which contained mainly pupae and some full grown larvae.

In general the toxic action of the DDT was manifest mainly in nonemergence from the pupae although some reduction occurred in the numbers of larvae which failed to pupate. One-day-old larvae appear to be more susceptible than newly hatched or 3-day-old larvae. At the less effective dosages of 62.5 and 125 mg. of DDT per sq. ft. a delayed effect in the toxic action can be seen in the increased percentages of defective adults. This phenomenon was observed in DDT-resistant strains by Tahori & Hoskins (1953).

Methoxychlor.—The tests with methoxychlor applications (Table 2) demonstrate that this compound even at 1250 mg. per sq. ft. had only a slight effect upon the normal development of the house fly larvae.

Table 2.—The per cent reduction as larvae, pupae, and adults of house flies after 5 ml. spray applications of methoxychlor emulsions on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250	−1	17	1	0	18
	1	4	3	1	8
	3	2	4	0	6
	5	2	2	1	5
750	−1	6	1	0	7
	1	4	9	1	14
	3	0	1	0	1
	5	5	2	0	7
250	−1	0	6	2	8
	1	3	6	1	10
	3	1	1	0	2
	5	4	2	0	6

[a] Results are the averages of six replicates each.

Toxaphene.—Results (Table 3) obtained against cultures of partially grown maggots (−1 to 3 days) with emulsions formulated with toxaphene were good at dosages of 25 or more mg. per sq. ft. Deposits of 25 mg. per sq. ft. appear to be a break point for toxaphene since the lower dosages showed little effectiveness on the −1 to 3-day-old cultures. Toxaphene had little effect even at 1250 mg. per sq. ft. upon the 5-day-old cultures.

Toxaphene apparently acted more rapidly than DDT since in most cultures treated with toxaphene the principal reduction occurred in the larvae. Toxaphene did not act fast enough, however, to prevent maggots, 3 days old at time of treatment, from completing pupation even at a dosage of 1250 mg. of toxaphene per sq. ft. Very few defective adults, which would indicate a delayed action, were seen with toxaphene even at the lower dosages.

BHC.—BHC (95 per cent gamma isomer content) proved to be a highly effective larvicide on cultures −1, 1, and 3 days old at dosages as low as 25 mg. per sq. ft. (Table 4). With BHC the break in larvicidal effectiveness on −1 to 3-day-old cultures appeared to be 12.5 mg. per sq. ft. Although BHC showed some activity on 5-day-old cultures, it still did not produce effective mortalities of the mature larvae and pupae at 1250 mg. per sq. ft.

The toxic action of BHC appears faster than that of DDT or toxaphene since the essential action generally took place before the larvae pupated, even in applications on 3-day-old cultures. Delayed action reflected in the occurrence of defective adults was not particularly evident. In studies with gamma isomer of BHC, Du Chavois (1947) found the compound nontoxic to house fly eggs, highly toxic to all the larval stages and comparatively ineffective against the pupae.

Chlordane.—At dosages of 250 or more mg. per sq. ft., practically complete mortalities were obtained with chlordane on cultures −1, 1, and 3 days old (Table 5). The break point for general larvicidal effectiveness was about 125 mg. of chlordane per sq. ft. The results on 5-day-old cultures with chlordane were superior to those obtained with any of the other insecticides tested. A few

Table 3.—The per cent reduction as larvae, pupae, and adults of house flies after 5 ml. spray applications of toxaphene emulsion on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	3	80	20	0	100
	5	4	4	0	8
750[b]	3	64	34	1	99
	5	5	1	1	7
250	−1	98	2	0	100
	1	91	3	0	94
	3	56	41	1	98
	5	12	1	0	13
125[c]	−1	99	1	0	100
	1	100	0	0	100
	3	88	12	0	100
62.5[c]	−1	96	4	0	100
	1	100	0	0	100
	3	63	36	1	100
25.0[c]	−1	85	7	3	95
	1	98	2	0	100
	3	16	56	11	83
12.5[c]	−1	15	0	0	15
	1	10	1	2	13
	3	1	1	0	2
6.25[c]	−1	17	0	0	17
	1	6	12	3	21
	3	1	0	0	1
2.5[c]	−1	12	2	1	15
	1	4	0	0	4
	3	3	0	0	3

[a] Results are the averages of six replicates each.
[b] Dosage gave complete larval mortality when applied to −1 and 1-day-old cultures.
[c] Dosage gave no mortality when applied to 5-day-old cultures.

Table 4.—The per cent reduction as larvae, pupae, and adults of house flies after 5 ml. spray applications of BHC (95 per cent gamma isomer content) emulsions on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	3	98	2	0	100
	5	1	16	4	21
750[b]	3	97	3	0	100
	5	8	35	4	47
250[b]	3	97	3	0	100
	5	1	12	2	15
125	−1	98	1	0	99
	1	100	0	0	100
	3	98	2	0	100
	5	11	21	3	35
62.5	−1	100	0	0	100
	1	100	0	0	100
	3	98	2	0	100
	5	12	26	5	43
25.0	−1	100	0	0	100
	1	100	0	0	100
	3	97	3	0	100
	5	27	17	8	52
12.5[c]	−1	70	7	5	82
	1	34	22	12	68
	3	56	24	6	86
6.25[c]	−1	54	2	2	58
	1	3	1	2	6
	3	16	18	17	51
2.5[c]	−1	25	0	0	25
	1	0	0	0	0
	3	12	1	1	14

[a] Results are the averages of six replicates each.
[b] Dosage gave complete larval mortality when applied to −1 and 1-day-old cultures.
[c] Five-day-old cultures were not tested.

Table 5.—The per cent reduction as larvae, pupae, and adults of house flies after 5 ml. spray applications of chlordane emulsions on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	3	100	0	0	100
	5	68	23	2	93
750[b]	3	99	1	0	100
	5	78	9	2	89
250	−1	99	1	0	100
	1	100	0	0	100
	3	94	5	0	99
	5	47	20	4	71
125	−1	84	10	1	95
	1	97	0	0	97
	3	20	22	7	49
	5	8	5	0	13
62.5	−1	53	23	6	82
	1	90	5	1	96
	3	14	12	4	30
	5	7	4	0	11
25.0	−1	29	14	7	50
	1	71	8	3	82
	3	11	6	5	22
	5	3	2	0	5
12.5[c]	−1	12	1	3	16
	1	8	4	1	13
	3	2	1	2	5
6.2[c]	−1	9	4	1	14
	1	7	0	0	7
	3	2	0	0	2
2.5[c]	−1	7	0	0	7
	1	2	0	0	2
	3	2	0	1	3

[a] Results are the averages of six replicates each.
[b] Dosage gave complete larval mortality when applied to −1 and 1-day-old cultures.
[c] Dosage gave no mortality when applied to 5-day-old cultures.

tests were made to ascertain the fumigant action of chlordane using a 25 per cent chlordane-xylene concentrate and injecting amounts equivalent to surface application of 1250 mg. of chlordane per sq. ft. 2 inches deep in 3- and 5-day-old cultures. Negligible mortalities were obtained but the chlordane fumes may have been confined in levels of the rearing media not used by the larvae and pupae.

The dosage of chlordane applied appears quite critical since, in comparison with toxaphene, it was superior at dosages of 250 or more mg. per sq. ft. but inferior at 125 or less mg. per sq. ft. to −1 to 3-day-old cultures. In general, the toxic action appeared rapid and effective against the immature stages present in the cultures with some evidence of delayed toxic effects.

Dieldrin.—Application rates of 250 mg. of dieldrin per sq. ft. were required for complete mortalities in cultures up to 3 days old (Table 6). A treatment of 125 mg. of dieldrin per sq. ft. seems to be the break point for this insecticide. On 5-day-old cultures, dieldrin produced total reductions of approximately one-half of the flies at dosages of at least 250 mg. per sq. ft.

Dieldrin in toxic action was like DDT in that many of the larvae were able to pupate and, at the lower dosage rates, delayed action was shown by the presence of defective adults in considerable numbers. Like DDT, dieldrin appears to be less effective against the newly hatched maggots in cultures of −1 day than it is against partially grown larvae in 1- and 3-day cultures.

Aldrin.—Applications of aldrin (Table 7) show this material to be effective on −1 to 3-day-old cultures at 25 mg. per sq. ft. with an apparent break point at 12.5 mg. of aldrin per sq. ft. Treatments of 5-day-old cultures gave results similar to dieldrin.

The toxic action of aldrin appeared quite rapid at the higher dosages since most of the larvae were eliminated before pupation while at lower dosages delayed effectiveness was demonstrated by the relatively high pupal reduction and by the number of defective adults.

General Comparison.—Most of the halogenated hydrocarbon insecticides tested showed a marked decrease in their effectiveness on 5-day-old cultures. On the basis of

Table 6.—The per cent reduction as larvae, pupae, and adults of house flies after 5-ml. spray applications of dieldrin emulsion on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	3	100	0	0	100
	5	9	39	3	51
750[b]	3	99	1	0	100
	5	17	35	3	55
250[b]	3	98	2	0	100
	5	13	31	4	48
125	−1	81	3	2	86
	1	97	0	0	97
	3	61	24	9	94
	5	6	0	0	6
62.5	−1	54	1	1	56
	1	86	8	3	97
	3	30	34	16	80
	5	10	0	0	10
25	−1	19	3	3	25
	1	76	8	3	87
	3	12	35	10	57
	5	3	2	0	5
12.5[c]	−1	2	33	18	53
	1	43	15	7	65
	3	34	43	12	89
6.25[c]	−1	0	6	8	14
	1	37	13	14	64
	3	6	33	10	49
2.5[c]	−1	0	0	1	1
	1	35	18	1	54
	3	4	6	9	19

[a] Results are the averages of six replicates each.
[b] Dosage gave complete larval mortality when applied to −1 and 1-day-old cultures.
[c] Dosage gave no mortality when applied to 5-day-old cultures.

general effectiveness against all four ages of cultures, chlordane at dosages of at least 250 mg. per sq. ft. is the insecticide of choice with aldrin, dieldrin, BHC, toxaphene, DDT, and methoxychlor showing decreased general effectiveness in the order named.

It should be noted that chlordane showed a definite break in general effectiveness between 125 and 250 mg. per sq. ft. On the basis of dosage requirements for the −1 to 3-day-old cultures only, BHC (95 per cent gamma isomer) appears to be the best insecticide since it showed complete mortalities even at 25 mg. per sq. ft. On the basis of dosage requirement the other insecticides in order of decreasing effectiveness would be aldrin, toxaphene, dieldrin, chlordane, DDT, and methoxychlor.

Based on rapidity of action against the immature stages of the house fly, BHC eliminated the larvae almost completely at dosages of 25 or more mg. per sq. ft. Aldrin and chlordane showed similar rapid action but at the higher dosages. With toxaphene, dieldrin, and DDT a considerable number of larvae pupated before succumbing to the toxic effects of the insecticide. Methoxychlor was essentially ineffective under the test conditions.

These results may be compared with similar applications of the halogenated hydrocarbon insecticides as house fly larvicides by Hadjinicolaou & Hansens (1953) who found aldrin and dieldrin practically equally effective, chlordane and toxaphene only slightly less effective, while much larger quantities of DDT, methoxychlor and lindane were necessary to give kills of maggots under laboratory conditions.

Summary.—Seven chlorinated hydrocarbon insecticides, DDT, methoxychlor, toxaphene, benzene hexachloride (95 per cent gamma isomer content), chlordane, dieldrin, and aldrin, were tested as larvicides in spray applications of emulsion formulations on the surface of breeding media at −1, 1, 3, and 5 days from the introduction of newly hatched larvae of nonresistant house flies. The effectiveness of dosages ranging from 2.5 to 1250 mg. of insecticide per sq. ft. was determined on the numbers of pupae and of defective and normal adults in treated cultures compared with check cultures.

On 5-day-old cultures containing mainly pupae and some full-grown larvae only chlordane at dosages of 250 to 1250 mg. per sq. ft. gave reductions of at least 70 per cent making it the best insecticide for general effectiveness. Against −1 to 3-day-old cultures, BHC, aldrin, toxaphene and dieldrin were more effective than chlordane at dosages below 250 mg. per sq. ft. BHC (95 per cent gamma isomer content) appeared to be the most active, giving complete mortalities at 25 mg. per sq. ft. and eliminating almost all the fly larvae before they could pupate.

Table 7.—The per cent reduction as larve, pupae, and adults of house flies after 5-ml. spray applications of aldrin emulsion on laboratory cultures of various ages.[a]

Application Rate (Mg./Sq. Ft.)	Age of Culture (Days)	Per Cent Reduction			
		As Larvae	As Pupae	As Defective Adults	Total
1250[b]	3	96	4	0	100
	5	5	29	8	42
750[b]	3	96	4	0	100
	5	12	29	7	48
250[b]	3	92	8	0	100
	5	5	23	2	30
125	−1	96	1	1	98
	1	99	1	0	100
	3	87	9	0	96
	5	6	1	1	8
62.5	−1	97	0	0	97
	1	99	0	0	99
	3	83	11	1	95
	5	13	2	1	16
25	−1	94	2	1	97
	1	97	0	0	97
	3	61	31	1	93
	5	7	3	0	10
12.5[c]	−1	71	13	7	91
	1	11	56	8	75
	3	15	74	6	95
6.25[c]	−1	52	5	7	64
	1	15	16	11	42
	3	4	47	17	68
2.5[c]	−1	9	9	1	19
	1	10	5	2	17
	3	6	13	13	32

[a] Results are the averages of six replicates each.
[b] Dosage gave complete larval mortality when applied to −1 and 1-day-old cultures.
[c] Dosage gave no mortality when applied to 5-day-old cultures.

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Field Studies on Larval Control of Black Flies in Guatemala[1]

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Onchocerciasis, a filarid disease transmitted by adult black flies (Diptera: Simuliidae) is endemic in the Western Hemisphere in parts of Guatemala, Mexico, and Venezuela. The largest endemic zone appears as a long narrow rectangular area on the Pacific slopes of the Guatemalan Sierra Madre range, its lower border at about 1,500 feet, and the upper at about 5,000 feet. A project investigating various phases of this disease, particularly with regard to the parasite, its hosts, and vector, maintained a laboratory for several years in the town of San Pedro Yepocapa, Guatemala, Central America. This town, at an altitude of 5,000 feet, overlooks the ocean some 50 miles away, and is near the upper boundary of the disease zone.

The eastern boundary of the municipality of Yepocapa, in which this town is located, is formed by the volcanoes Fuego and Acatenango. The foothills of these mountains slope toward the Pacific, as do the main drainage systems of the municipality. The terrain is extremely rugged because of the mountains and deep gorges cut by the streams. The total annual rainfall of about 120 inches all comes during the rainy season from May to November, the remaining months constitute the dry season. Although black fly breeding (in the permanent streams) is continuous throughout the year, rainfall is an important factor, its effects on stream conditions being reflected in seasonal fluctuations in the larval and adult black fly populations.

Black fly field control studies were preceded by laboratory investigations which led to the development of a technique for screening chemicals as possible larvicides, and the testing of several hundred such compounds (Lea & Dalmat, 1954). This was followed by preliminary field tests with various commercial insecticides applied as larvicides to determine their effectiveness in different types of streams. Finally, a small-scale program was carried out to study the problems involved in reducing the vector population by larviciding all streams within a given area. The present paper is concerned with the second phase, preliminary field trials.

Fairchild & Barreda (1945) working in this same region of Guatemala had found DDT applied for 1 hour at the rate of 0.1 part per million to be highly effective in controlling black fly larvae for distances up to 10 kilometers in certain streams. In Alaska, Gjullin *et al.* (1949), making tests in sections of streams, reported that DDT in acetone at 0.3 p.p.m. for 15 minutes gave the best larval control. Vargas (1948) recommended the use of 1 p.p.m. applied for 30 minutes to control the simuliid vectors of onchocerciasis in Mexico, and later (1951) suggested 5 p.p.m. for the same period. Kindler & Regan (1949) using 200 foot sections of streams found that TDE at 0.05 p.p.m. and DDT at 0.2 p.p.m. for 10 minutes gave nearly complete control 1½ hours after application. TDE gave good results at 0.2 p.p.m. for 10 minutes. Hocking *et al.* (1949) obtained good control of larvae with DDT at a minimum dosage of 0.1 p.p.m. applied for 15 minutes. Lindane at the same rate was about 50% effective, and chlordane at 0.127 p.p.m. for 15 minutes gave partial control. Hocking (1950), after having tested DDT, parathion, BHC, aldrin, dieldrin, methoxychlor and 1,2,4-trichlorobenzene, concludes that DDT is still the most satisfactory insecticide.

DESCRIPTION OF STREAMS.—Considered as a single group, breeding of the three most important anthropophilic species of Guatemalan black flies, *Simulium ochraceum*, *S. metallicum*, and *S. callidum*, occurs in streams of all sizes, in those with volumes of only 10 gallons per minute up to large rivers. Thus, it was necessary to conduct preliminary larviciding experiments in streams of all sizes and under various conditions. The results of this study were then to serve as a basis for planning a small-scale vector eradication campaign.

The streams in the Yepocapa region could be categorized into three general groups on the basis of their volume. The smallest were rivulets ranging in volume from 10 to 100 gallons per minute; the intermediate group was composed of small streams with volumes between 100 and 1,000 gallons per minute; and the large streams ranged from 1,000 to 20,000 gallons per minute. The latter group represents the largest size stream tested in the Yepocapa region (Fig. 1a). However, outside the municipality several large rivers with volumes of 90,000 to 100,000 gallons per minute were treated.

Those streams constituting the first group were short rivulets often originating as collections of cliff or surface seepage, generally less than one foot in width and only a few inches deep. The channels were ill-defined and winding, full of debris, and with trailing leaves of plants growing in or adjacent to them. The stream bottoms were of mud and usually with few stones; the water surface was smooth and unbroken; the current sluggish. The majority of these rivulets did not flow over 100 to 200 feet before emptying into a larger stream. All streams gradually decreased in volume as the dry season progressed, and many of these small rivulets were present only during the rainy season.

The intermediate size stream generally began as a small rivulet which was joined by others along its course, increasing to several hundred gallons per minute before flowing into the large streams. These were, for the most part, longer (up to 5,000 feet) than the rivulets. They had a definite channel, often with steep walls and with mud, sand, or gravel bottoms. In some places, large rocks created falls and pools. Plants with trailing parts grew only along the bank when the streams were full. During the dry season as the water table lowered, many of these streams emerged several hundred feet further downstream than they did during the rainy season. The volume, too, changed drastically, often dropping as much as 90% in dry season.

The region of Yepocapa contains a vast network of rivulet-fed streams. In an area of approximately 75

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FIG. 1.—a) One of the main streams (30,000 gallons per minute) in the municipality of Yepocapa, Guatemala. b) A small rivulet (35 gallons per minute) flowing under a heavy cover of vegetation, one of hundreds of such black-fly breeding places, is being treated for 3 minutes. c) Treatment for 1 hour using "floating siphon" larvicide dispenser. Stream volume 250 gallons per minute. d) Searching for larvae 24 hours after a larvicide treatment, while measuring the distance of kill downstream from the point of application to the first larva. Stream volume 2,000 gallons per minute.

square miles, there were over 1,500 small streams and rivulets during the dry season. The greater proportion of the small rivulets were located in the higher altitudes of the municipality, while more of the intermediate type of streams were found in lower and more coastal parts of the region.

With two exceptions, all the large streams near Yepocapa began as small streams or rivulets which gradually increased in volume as they were joined by their tributaries. On the mountainsides these large streams had cut deep gorges which broadened out at lower altitudes. Their beds were of sand, gravel, and boulders, which formed numerous falls and pools, making the water surface turbulent. Trailing vegetation grew along the banks, and throughout the year the changes in the volume of these streams were less evident. There was little turbidity in any of the streams at any time.

EQUIPMENT AND METHOD FOR LARVICIDING.—Of the streams in the Yepocapa region important as breeding places of the anthropophilic species of *Simulium*, the greatest number had volumes less than 100 gallons per minute. In such small streams it was difficult to calculate the rate of flow by the same methods used in the larger streams where the rate could easily be determined by timing a floating object over a measured course or by mechanical devices such as the pygmy current meter. However, the work did require a simple, rapid, and portable means of making numerous volume determinations in the field. For this, a small metal canal (Lea 1955) was constructed which had been previously calibrated to indicate directly the flow in gallons per minute, when a stream was channeled through it. The canals used were satisfactory for volumes from 10 to 120 gallons per minute.

Chemicals to be field tested were supplied or prepared as emulsion concentrates. The quantity of larvicide used in treatment of a particular stream was calculated as that necessary to give the desired parts per million concentration in the total volume of water flowing during the treatment period (volume of water per minute×duration of

Table 1.—Results of stream tests to determine the distance to which black fly larvae were completely eliminated by one larvicide treatment.[a]

Rate of Flow in Gal./Min. at Point of Treatment	Distance in Feet of Larval Control in Streams[b] Dosage (p.p.m.) and Time (Min.)			
	DDT 0.1 60	DDT 0.1 3	DDT 2 3	EPN 0.1 3
20		90	200	
35		200		
50		160		
80	800	225		
100				900
200				1,200
250	900			
270		600		
300			1,700	
400		1,400		
600	4,800		3,100	
800		2,000		
900	8,000			
1,000				1,800
1,500	12,200	3,500		
2,000	13,700	3,000		
3,500		7,500		
4,300			14,000	
4,500	18,000	9,600		2,800
10,000	30– 40,000	11,000	20,000	
90,000	100–150,000			
100,000		15,000		

[a] Several insecticides were tested, and various combinations of concentration and duration of application in streams of different volumes were compared.

[b] A single treatment of each of the following insecticides applied at 0.1 p.p.m. for 3 minutes gave the following control (rate of stream flow in gallons per minute at point of treatment is given first, followed by the distance in feet of larval control in streams): chlordane, 450–1,800; dieldrin, 200–900; parathion 450–1,800; heptachlor, 80–300, 2,000–2,400; 4,300–5,600; methyl parathion, 175–1,100.

application). Treatments of short duration (3 to 30 minutes) to low volume streams which required only a relatively small amount of emulsion concentrate, were made by siphoning the toxicant into the stream from a can or bottle in which the concentrate had been diluted with the quantity of water necessary to prolong the application of the test material over the desired period (Fig. 1b).

In some of the larger streams, experiments were conducted in which the larvicide was applied over a 60-minute period. These tests of course, required larger quantities of the toxicant. Instead of hand-pouring, the emulsion was put into a 5-gallon can which had been designed to empty in 60 minutes by means of a "floating siphon" (Fig. 1c and Lea 1955). This, in effect, lowered the siphon in the can at the same rate as the water level in the can and dispensed the material at an even rate over 1 hour.

Prior to treating a stream, the trailing leaves or debris on which larvae could be expected to be found were examined and the number of larvae recorded. This was done at ten points along the length of the stream. In the larger streams sections were examined at several accessible places along the course to determine that an adequate larval population was present. Twenty-four hours after treatment another examination of the stream was made.

Actual measurement of the length of the stream from which larvae had been removed was made by two men using a 200 foot tape (Fig. 1d). Carefully inspecting sites favorable for larval attachment while giving particular attention to the places checked in the pretreatment survey, they worked downstream from the place of treatment to the point where the first larva was found.

The results recorded, therefore, were based only on distance of complete clearing of the stream, and no attempt was made to estimate distance of partial control. Although it appeared that the larvae were killed, rather than that they migrated downstream, efforts to determine the actual fate of the larvae in a treated section of a stream were unsatisfactory. This was the case because it was not possible to distinguish among larvae caught in nets or traps, those which had been killed outright by the insecticide from those which had been killed by the force of the water and the pounding of sand and silt after they were caught in the trap. However, by knowing how far downstream complete elimination of larvae could be expected, it would be possible in a very long stream to treat at several points in order to assure clearing larvae from the stream for its entire length.

STREAM TESTS.—Because of the diversity of types and sizes of streams in the region, some insight was needed as to the effectiveness to be expected from larvicide applications of DDT and similar toxicants in the various streams. In all, several hundred treatments were made to individual streams in order to collect the necessary data.

The small rivulets of less than 100 gallons per minute constituted about 85 to 90% of the black fly breeding streams which would have to be treated in a vector control program in the Yepocapa region. Therefore, it was in these streams that first field experiments were made.

DDT applied as a wettable powder at the rate of 10 p.p.m. for 30 minutes failed to eliminate larvae for more than a few feet in any of the rivulets treated. DDT emulsion, on the other hand, was found to control larvae effectively when used at 1 p.p.m. for 60 minutes or 30 minutes. Subsequent tests, in which the concentration was reduced to 0.1 p.p.m. applied for 30 and 15 minutes, produced similar results. A further cut in the concentration of the DDT to 0.001 p.p.m. left the larvae unharmed, but in one trial the emulsion at 0.1 p.p.m. was applied for only 3 minutes and still gave as effective control in short rivulets as treatments of greater duration. Repeated tests confirmed the fact that DDT at 0.1 p.p.m. for 3 minutes would eliminate larvae for a distance of at least 100 feet in rivulets of 20 gallons per minute flow and for 200 feet at 40 gallons per minute flow. It was encouraging to find that a treatment of such a short duration was so effective in the small rivulets, for it would mean a considerable reduction in the number of man-hours spent in larviciding the hundreds of short rivulets which had made larval control in this area seem almost impossible. Although, as can be seen in table 1, a 60-minute treatment at 0.1 p.p.m. in an 80-gallons-per-minute rivulet killed larvae for 800 feet, the majority of the rivulets were much shorter and, therefore, the 3-minute period could satisfactorily be used, permitting a saving not only in time, but also of material and its transportation in the field.

This success stimulated tests of the same duration and concentration in larger streams, for the question now arose whether kill for 200 feet was actually the maximum obtainable with the short application period. Again, from table 1 it can be seen that the distance of control was ex-

tended in larger streams, and in fact, the greater the volume of the stream, treated at 0.1 p.p.m. for 3 minutes, the greater the distance of kill. Figure 2 shows this relationship more clearly. However, in streams of volumes greater than 4,500 gallons per minute, the application of 0.1 p.p.m. for 3 minutes did not produce the same proportionate increase in distance of kill.

DDT applied at 2 p.p.m. for 3 minutes was somewhat less effective than at 0.1 p.p.m. for 60 minutes, although the same quantity of insecticide was involved. The latter concentration applied to a river of 90,000 gallons per minute flow, completely eliminated larvae for approximately 20 to 25 miles (Table 1). Beyond that point the river was inaccessible, and because accurate maps for any of the large rivers were lacking, distances had to be estimated. From the data in figure 2, there is no indication that in this test, a maximum distance of kill had been reached, even at 20 miles for the 1-hour treatment. In addition, a number of tests using other combinations of concentration and duration of application were made with DDT and other insecticides, a few of which are included in table 1.

Although only one test was conducted with DDT at 0.05 p.p.m. for 60 minutes, it cleared a stream (100 gallons per minute) of larvae for 550 feet, which indicates that it might also be of some use in streams of larger volume. At 0.005 p.p.m. over a 60-minute period, DDT was effective for 160 feet in a stream of 125 gallons per minute.

EPN and heptachlor gave substantially better control than DDT only in streams of less than 500 gallons per minute, while in the larger streams, DDT, compared at the rate of 0.1 p.p.m. for 3 minutes, was toxic over a longer distance than any of the other insecticides tested. This was surprising in the light of high toxicity exhibited in the laboratory by EPN, heptachlor, and related compounds, but no explanation for it can be given. No effect on the larvae was produced in any of the streams treated with lindane.

DISCUSSION.—When an insecticide is applied to running water for the control of black fly larvae, it is effective at any particular point in the stream only for the short time it is actually in contact with the larvae therein. The extent of this toxic period is controlled by the duration of the treatment period. As soon as all the insecticide has passed, the stream can become reinfested with larvae, either by egg deposition or larval migration. Exposure to the insecticide can be prolonged by increasing the treatment period, but there can be no "residual action" of a larvicide. Furthermore, even though the water of the breeding stream itself offers the most efficient means of transporting a toxic material, the lethal effect of the latter cannot continue indefinitely.

Since there was such a wide range in the volume and character of the breeding streams found in the onchocerciasis zone of Guatemala, one of the most important phases of the field control studies was determining the relation of the toxic material, concentration, duration of the application, and the stream-volume to the distance over which one treatment would clear a stream of larvae.

As has been shown by the data presented for DDT, (Figure 2) a change in the concentration or application period resulted in a different distance of kill for each different stream-volume tested. In general, the greater the volume of the stream treated, the greater is the distance of complete larval control. However, it should be reiterated that for DDT at 0.1 p.p.m. applied for 3 minutes, the proportionate increase in the distance of kill appeared to be less beyond approximately 4,500 gallons per minute. This may also be true for treatments with higher concentrations or longer application periods. However, no such limit was reached in the largest Guatemalan rivers so treated.

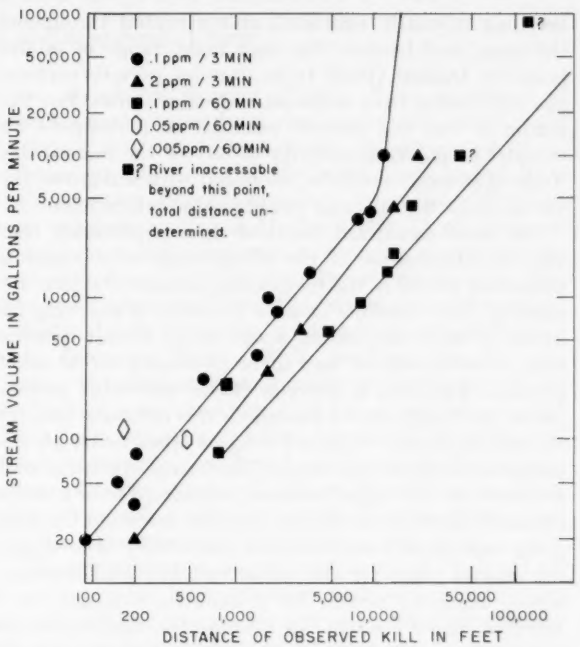

FIG. 2.—A comparison of the distance of kill of black fly larvae in streams of different volumes, varying the concentration of DDT and duration of application. Plotted on Log × Log scale.

No doubt the distance of kill is largely controlled by the rate of dilution of the larvicide with water from tributaries, as well as the rate of "settling out" of the insecticide. With regard to the latter condition, at least two factors appear to be important: (1) current speed, and (2) turbulence of the water. The small rivulets were so sluggish that the water's surface was rarely broken. The larger streams, on the other hand, were swift and contained numerous rocks and boulders which created small falls and ripples. This churning produced greater mixing action, and thereby prolonged the time during which the emulsion would remain in suspension.

Certainly the results of experiments in swift mountain streams cannot be taken as a true indication of the effectiveness in the more sluggish streams of the coastal plain, anymore than test data from one country can be expected to reflect exactly the outcome in another, but the principles and techniques developed in one area may be useful elsewhere. The effectiveness of a larvicide must be determined in the various size streams of each region by actual tests.

In Guatemala, any larviciding control program would be a year-round project over a large area since black fly

breeding normally continues uninterrupted throughout the year, and because the long flight range of adults, found by Dalmat (1952) to be 10 miles, permits continuous infiltration from adjacent untreated areas. For this reason it was not deemed essential to investigate the ovicidal or pupicidal activity of any of the insecticides. Treated streams would be reinfested with full-grown larvae in about 3 weeks and would require retreatment.

The most significant result of these preliminary tests was the observation of the effectiveness of a 3-minute treatment period in the rivulets and smaller streams. Because of their numbers and the difficulty in reaching the source of each, larviciding would be an almost hopeless task if the treatment had to be prolonged for 30 or 60 minutes. Fairchild & Barreda (1945) and other investigators have suggested overcoming this difficulty through the use of plaster of paris blocks or other materials impregnated with an insecticide. The transportation of such materials in this rugged area was considered to be a major obstacle. However, it was felt that the results of the foregoing experiments indicated the plausibility of formulating control plans for the major endemic onchocerciasis zones, using 0.1 p.p.m. for 3 minutes, 2 p.p.m. for 3 minutes, and 0.1 p.p.m. for 60 minutes. Such schedules would prove sufficiently flexible to meet existing conditions while keeping the man-hours spent in making the applications within economical limits.

There is no doubt that 0.1 p.p.m. for 3 minutes is the most practical treatment in the short rivulets and in the intermediate size streams, even though in some of the longer ones a number of treatments at several points along the streams course would be required. As for the largest streams, the best criterion for choosing the treatment is the accessibility of the particular stream. Generally, in streams of less than 5,000 gallons per minute, a 3-minute application at 0.1 p.p.m. at three points along the stream would achieve the same result that six to seven times the amount of material and time (i.e., 0.1 p.p.m. for 60 minutes at one point) would accomplish. In some of these intermediate size streams and in those over 5,000 gallons per minute, either 2 p.p.m. for 3 minutes or 0.1 p.p.m. for 60 minutes could be used to greater advantage. Cost of materials permitting, EPN or heptachlor might be used to similar advantage in the numerous short rivulets, and DDT in the large streams.

SUMMARY.—In Guatemala, investigations of onchocerciasis included studies of black fly control by larviciding streams. The breeding streams in the region of the laboratory were grouped by volume as follows: (1) rivulets, 10 to 100 gallons per minute; (2) intermediate streams, 100 to 1,000 gallons per minute; (3) large streams, 1,000 gallons per minute and up. In all, several hundred treatments were made in streams of each group to ascertain the most economical combination of treatment time and concentration for DDT and other insecticides, as determined by the distance in the stream which was completely cleared of larvae.

Tests were made to determine the relationship of insecticide material, concentration, application period, and stream volume to the distance of kill attainable with one treatment. It was found that for DDT at the rates of 0.1 p.p.m. for 3 minutes, 0.1 p.p.m. for 60 minutes, and 2 p.p.m. for 3 minutes, the greater the stream-volume at the point of treatment the farther the insecticide would be effective in a stream. However, DDT at 0.1 p.p.m. for 3 minutes, which was effective for about 2 miles at a volume of 5,000 gallons per minute, appeared to have reached the limit of its effectiveness at that volume, for beyond it, the distance of kill showed relatively little increase. Such a limit to the effective distance of control was never attained with DDT at the 0.1 p.p.m. concentration applied over a 1-hour period, the largest river so treated having a volume of 90,000 gallons per minute.

In any future larviciding program treatment with 0.1 p.p.m. DDT for 3 minutes in the short rivulets and most intermediate size streams, which constitute 90% of the breeding streams in the area, would make possible important savings in man-hours spent in making the applications as well as reducing the amount of material which would have to be transported in the field over rugged terrain. In streams over 5,000 gallons per minute either 2.0 p.p.m. DDT for 3 minutes or 0.1 p.p.m. for 60 minutes should be used.

Of the many other insecticides tested, EPN and heptachlor gave control similar to that with DDT only in streams of less than 500 gallons per minute. Either of these compounds could be used to advantage in the smaller streams, while DDT could be reserved for the larger streams.

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The Need for Common Sense in the Control of Insect Pests[1]

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Several years ago, at one of these meetings, I sat down by one of my old friends from the Cotton Belt, and, by way of making polite conversation, I asked, "Well, how did you make out with the boll weevils this year?" He replied, "Man, we had plenty of them, but we got wonderful control." After a moment's pause, he continued, "But I tell you the bollworms nearly ate us up." This incident amused me no end, but it is the kind of story that has been repeated time and again during the past few years. The use of chemicals that solve one problem but create another, requiring another chemical which in turn may possibly require still another does not make very good sense, to say the least.

This problem which Pickett (1949) calls, "trading one pest for another" has been well recognized. Some people manifest alarm, while others, I presume, make little of the situation. It is my thought that it might be well at this time to assemble the information at hand, take stock of the situation, and present again some of the ideas that have been advanced. Some of what has been said may well bear repeating.

To review some of the things that have happened, it might be pointed out that in addition to trading or swapping boll weevil for bollworm, codling moth has been traded for red-banded leafroller (Gould & Hamstead 1948), mites (Steiner, *et al.* 1944), mealybugs (Hough *et al.* 1945) aphids, (Newcomer & Dean 1953) and scale insects (Michelbacher *et al.* 1946). The plum curculio on peach has been traded for Forbes scale (Chandler 1950). Sometimes the element of trading may be unapparent or absent. Serious outbreaks of Florida red scale accompanied by increased populations of rust mites, red mites, and mealybugs followed the use of DDT on citrus trees (Griffiths & Thompson 1947). As summarized by Solomon (1953), the use of chemicals on plants accounts for increased infestations of six species of mites, eight species of scales, two species of mealybugs, the citrus aphis, woolly apple aphis, white apple leafhopper, orange tortrix, and the eye-spotted bud moth.

From my own experience I should like to mention two cases, not so much because they are profound, but, rather, amusing in retrospect. When parathion aerosols were first used for the control of greenhouse pests we had an excellent cooperative relationship with a rose grower, and we were fairly basking in the warmth of his satisfaction with the control of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. After a few months of this the soft brown scale, *Coccus hesperidum* L., began to appear and in a short time the roses were fairly plastered with scale and a sticky, black mess.

On the University of Illinois campus we have had great fun trying to control terrific scale, mite, and aphid infestations on elms brought on by the application of DDT concentrates to control the leafhopper. *Scaphoideus luteolus* Van D., the vector of phloem necrosis. The program, started in 1949, called for two foliar applications of 6 per cent DDT to be applied by mist blower. By 1952 dying limbs and branches focused attention on an alarming scale infestation, which turned out to be Putnam scale, *Aspidiotus ancylus* (Putn.). From a survey of branch samples taken from elms we learned that it could be found only by diligent search on unsprayed trees, whereas on sprayed trees, the infestations varied from slight to severe, depending on how many times they had been sprayed (English & Decker 1954). In addition, on sprayed trees, the aphid population went up and infestations of the two-spotted spider mite became so severe that the elm foliage turned brown by late August and dropped prematurely. Furthermore, we had trouble with Flecher scale, *Lecanium fletcherii* Ckll., on Taxus sp., the oak kermes, San Jose scale, and mites on shrubs, as well as ornithologists and amateur bird lovers who complained about the birds that were killed. Apparently this intensive spray program created a new environment which made a mess of things in general. I hope the day never occurs when we create, either by expedient design, neglect, or ignorance, such an environment on a large scale.

This pyramiding of one problem on another cannot always be avoided. The public demands action and people are not satisfied to live in peace with flies, mosquitoes, and cockroaches. Farmers, orchardists and all producers of agricultural products want to use the latest and best available weapons to prevent losses. This pressure is a matter that at times may drive any of us to make hasty recommendations on the use of new insecticides. Perhaps we sometimes contribute to the build-up of this public pressure by our desire to "git there fustest with the mostest." However, unless we quickly recognize and face the problems that have been created and those that may be created by the improper use of insecticides, we will become uneconomic entomologists instead of economic entomologists.

Most of these insecticide-created pest problems have been laid at the feet of DDT, but BHC, chlordane, parathion, cryolite, various sulphur and lime sulphur sprays, zinc and copper sprays, tar oil and kerosene, and HCN, have been reported as responsible for increases in certain insect pest populations (Solomon 1953). However, it should be kept in mind that the exciting compound, DDT, has controlled more pests, saved the lives of more people, and stimulated more research than any other insecticide developed thus far. The important role played by DDT in the field of public health both in war and peace has been stressed by Wigglesworth (1945) and Knipling (1953). It and other new insecticides have not only benefited the life and health of the peoples of the earth, but they have increased our capacity to produce food and fiber (Decker 1954). These are worth-while considerations and we must not lose sight of them. At the same time it seems only fair to note that when we consider the wide variety of problems created by DDT, the secondary pest problems, the residue problems with milk, food, and feed, all the toxicological problems, the insect resistance problems and efforts to unravel resistance, DDT has also been our most costly insecticide. Far

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from abolishing the need for entomologists, as predicted at first, it started a chain reaction which created a vast new demand for entomologists and chemists. It was perhaps unfortunate indeeed that DDT blew in like a storm, but the demands for the things it would do were so great, the results so spectacular, and all of us were so eager, that many mistakes were made. DDT is now being evaluated, delimited, and placed in its proper channel.

Practically all of this "pest trading" has come from the use of chemicals on plants. The protection of plants is fundamental, but lest we lose proper perspective and "throw out the baby with the bath," we should keep in mind that the protection of plants is not the only demand on economic entomology. Almost the entire structure of measures for the control of stored product pests, household pests, disease carrying pests of both man and his domestic animals stands on the use of chemicals. The structure is a very solid one, too, it seems to me.

While we may deplore mistakes that have been made, we cannot join wholeheartedly with those who are always afraid of upsetting the "balance of nature," for as Claude Neiswander (1954) pointed out, man is interested in upsetting the balance of nature in his own favor. On the other hand, the great benefit to be derived from natural control agencies should always be taken into account. Indeed one of the good things the new insecticides have done is to make us acutely more aware of the great power and essential need of natural agencies (Clausen 1954). Nevertheless, an entomologist, charged with the responsibility of controlling the pests in his state, would find it difficult to convince a farmer that he should sacrifice 20 per cent of his current crop in favor of the "long term" outlook, if means were at hand to prevent such a loss.

Many of us would find it equally difficult to join that smaller group, I hope, which expects to solve the pest problems by chemicals alone. The criticism has been made that many entomologists have become involved in the mere testing of chemicals for insecticidal properties (Decker 1950), (Solomon 1953). This may be true, but the testing of chemicals is an important phase of economic entomology. Fortunately, a great part of this preliminary testing is being done by the chemical industry and it is to be hoped industry will take on more and more of this responsibility.

What, then, can be done about this matter of swapping one pest for another or correcting the pest problems that have been created by the improper use of insecticides? I don't propose to have all the answers. I have only a few suggestions, mostly borrowed, and the hope that some thought may be stimulated.

To illustrate my first point let me go back, if I may, to the conversation with my Cotton Belt friend. When he told me that the bollworms nearly ate them up, I replied, "Don't you know that the only way to keep out in front of this insecticide 'rat race' is to do nothing? This was a facetious remark, of course, but it seems to me there are times when it may be better to do nothing than to go off "half-cocked." Too often we are so stimulated by the mere glimpse of a problem that we jump on the nearest jet-propelled horse and "ride off in all directions at once." No doubt most of you can recall experiences when the sensible thing would have been to do nothing.

Just this past summer we were asked to investigate an infestation of mites on soybeans. The infestation was heavy and the beans had already been severely damaged next to a clover patch from which the mites apparently had migrated. There was a considerable infestation of thrips, in addition to the mites, on the undersides of the leaves and it was plain that a good proportion of the mites was dead. This situation led us to suspect that the thrips were predaceous and our suspicions were confirmed when Dr. Stannard identified the species as *Scolothrips sexmaculatus* (Perg.). On the basis of the anticipated performance of *Scolothrips* we were fortunate in preventing the farm adviser from sounding an alarm. It is clear, therefore, that while it may be safer for the doctor to operate, when in doubt, it may not be the sensible thing to do do. A negative recommendation may require a broad background of biological and taxonomic information, as well as the willingness to go "out on a limb."

Secondly, we should try to avoid the mistakes of the past. Let us hope that we do not get caught in another "DDT storm." The warning signs are up and cautious procedure is indicated. For example, the excessive and repeated use of lead arsenate poisoned the soil in some of our orchards making them unfit for the growth of cover crops (Vandecaveye *et al.* 1936). Some of our cotton soils were injured by repeated applications of calcium arsenate (Albert & Paden 1931). Ginsburg & Reed (1954) found DDT accumulations ranging from 35 to 113 pounds per acre in the soil under apple trees as the result of insect control for a period of only 6 years. While many crops will tolerate these DDT deposits, Fleming's (1947) report states that 25 pounds per acre of DDT in the soil may retard onions, soybeans, tomato, lima bean, bush bean, spinach, and certain ornamentals. The soil residue problem is complicated by the fact that a stable chemical leaves the soil slowly and the rate of loss may vary with the type of soil (Fleming & Maines 1953). The fertilizer used in conjunction with the soil insecticide may accentuate injury to the crop (Morrison *et al.* 1948) or the soil treatment may create a severe mite problem (Klostermeyer & Rasmussen 1953). It is evident that this matter should be given a great deal of attention both in thought and research, because any measure that damages the soil or jeopardizes its fertility is fundamentally wrong. For this reason the use of residual chemicals in the soil on anything but an emergency basis should be deferred until thorough research establishes the innocuous properties of such chemicals. Likewise, the incorporation of insecticides in fertilizers with the possibility that farmers may use such mixtures as routine practice, should be approached slowly. The application of soil insecticides might be more sensibly made by the use of equipment that will apply the insecticide and fertilizer separately but simultaneously as suggested by Jacob (1954). In this way the rates can be controlled and a host of other problems solved. While recognizing the need for soil insecticides, perhaps we should keep in mind that insecticides are by no means in the same categry as fertilizers.

Another mistake to be avoided has to do with resistance. It would seem that we know enough about resistance by this time to keep from running into it head on, as we have in recent years. It appears clear that if a highly

efficient residual insecticide is continuously used on a species with a high biotic potential, resistance can be anticipated. Therefore, the possibility of approaching such problems from all angles should be explored.

Thirdly, we who have been occupied with chemical control practices have, too often perhaps, ignored or minimized the help that can be obtained from natural agencies. I cannot visualize the development of an agricultural system in which all pests could be controlled through the use of knowledge obtained by a study of life histories, seasonal histories, plant resistance, and ecological factors. While it is needless to say that work in these phases of entomology should be broadened and intensified, it seems to me that our problems will not be solved by biologists, geneticists, or ecologists going off in their respective corners to follow their interests any more than they will be solved by those who do all their thinking in terms of sprays and dusts to the exclusion of biology. We need biologists, ecologists, and plant geneticists who can recognize the necessity for the use of insecticides and we need entomologists as well as chemists who appreciate and recognize that natural control agencies are indispensable. All of us appreciate the complexity of a system where plants and animals, rain and flood, and drouth, snow and ice and wind, poor soil and rich soil are all mixed together. Such a system is highly dynamic rather than static and the system is being constantly changed by man to meet his needs. The introduction of chemicals into this complex is only one of the facets of the system. It is evident that we need to recognize what Glen (1954) calls the "oneness of the science of entomology." This seems to call for a broader base in the training of entomologists, rather than a trend toward specialization.

The fourth suggestion involves a greater recognition of the intriguing possibilities for integrating chemical and natural control practices. This can be done by the proper timing of the insecticide application as suggested by Ullyett (1948), by the use of chemicals less destructive to parasites and predators, by better control of dosages and exposures (Ripper 1944), or a combination of these measures. Lord (1947, 1949), MacPhee (1953), Pickett & Patterson (1953), MacPhee & Sanford (1954), found that DDT, parathion, and sulphur almost completely destroyed the natural enemies of their orchard pests, whereas other chemicals killed only a few or none at all. By making certain substitutions in former spray programs pest control was obtained with fewer spray applications. In a similar way Glick & Lattimore (1954) found that the proper timing of the treatments and the choice of the right chemical permitted beneficial insects to survive while the injurious insects on cotton were reduced to a low population. The aid of natural agencies in walnut aphid control in California was obtained by the use of nicotine in place of such things as BHC, parathion, malathion, and TEPP (Michelbacher 1954). To be sure, such results are not easy to obtain and require much detailed study, but only by such integration can we find solid footing.

The fifth point is a challenge to the chemical industry. We now have insecticides whose dosage is measured in ounces per acre. If we had a chemical which would kill all the grasshoppers on an acre with a dosage of 1 gram, it would be progress of a sort, but what that gram of chemcial really should do is kill grasshoppers and nothing else. It is refreshing to note that this need for specific or selective insecticides is not only recognized by such academic workers as Pickett (1949), Wigglesworth (1945), Solomon (1953), Michelbacher (1954), and others, but by industry, as well. Lest we get the notion that industry is interested only in producing chemicals with broad insecticidal possibilities, I should like to quote a paragraph from the paper read by Roy Hansberry (1954) before this Society last December: "There is little question that more and more highly specific insecticides will continue to be developed. In fact I think there is an absolute necessity for the development of highly specific materials and for more restricted and intelligent use. Maybe this is going to complicate the industry to an almost unbearable extent, but I can see no other way out." Some of our acaricides are a step in the right direction. TEPP appears to point in the right direction, as does nicotine, rotenone and perhaps others. I am still confused by systemics, but I will endorse the idea as one well worth exploring, although in view of the recent work by Ahmed *et al.* (1954) the idea that systemics may kill noxious pests without harm to their natural enemies seems a bit optimistic. No little progress has been made in the development of newer chemicals to repel flies, mosquitoes, and chiggers, but the use of repellents on crops has not advanced much beyond the application of lime and wood ashes.

Certainly no chemical firm wishes to market insecticides that will "backfire." Once we allow growers to plunge into insecticidal programs that create more problems than they solve, programs that cost more than they return, programs that may ultimately jeopardize rather than increase production, we may have a severe setback in the development and use of insecticides.

In addition to the points already mentioned, I feel that we need quantitative data on the actual return per acre obtained by a given insecticidal program. Where destruction of a crop is threatened, such as when there is an invasion of armyworms, the returns are obvious. But in marginal cases requiring fairly regular use of insecticides we need to set up plots for yield records to determine if it will actually pay to carry out such a program over a period of years. For example, we need to know how much more money, if any, the grower will make by spraying his fruit trees six times instead of five or four times. Agronomists and horticulturists utilize a great acreage of land for experimental work. They even run test plots for a 100 years. Surely pest control is important enough to demand the land and facilities needed to evaluate control measures on more than a year to year basis and without depending on the generosity of a cooperative farmer or grower with whom it is nearly always necessary to make compromises in the treatments, collection of data, or disposal of the product.

The closing suggestion is borrowed from my colleague, George Decker (1950), who surmised several years ago that insecticides are "fire-fighting, and not prophylactic weapons." Fire fighting is more spectacular and exciting than fire prevention. Likewise the use of insecticides may

give more spectacular results than the hum-drum sanitary or biological measures, but so long as we maintain a proper perspective, predicate each move on careful studies, make deliberate rather than hasty decisions, and insist on honest rather than expedient recommendations, we can not only put out the fire, but we will do a good job of fire prevention.

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The Alfalfa Weevil in Delaware, 1953–54[1]

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This paper presents observations on the behavior and control of the alfalfa weevil, *Hypera postica* (Gyll.), adults of which were first discovered in Delaware on April 17, 1952.

Character and Extent of Injury.—Earliest evidence of adult spring feeding in 1953 was in and adjacent to isolated low grassy spots, as well as along margins of fields. These situations, evidently preferred for overwintering, were the points from which such injury spread. In 1954, initial injury was less restricted in all fields observed. Adults scar growing stems, feed on leaf epidermis producing whitish blotches, make irregular cuts in the margins of leaves, sever leaflets and growing tips of branches, and puncture stems for oviposition. However, damage by them is negligible compared to that done by larvae. Small larvae feed principally at the growing points on folded leaves. Larger larvae feed between the veins of unfolded leaves, causing a shredded or tattered appearance (Fig. 2). Hawley (1932) reported that from two-thirds to three-fourths of the total food requirements is consumed by the fourth instar; hence, it follows that proportional damage can be ascribed to the activity of this last larval stage.

In Delaware, serious damage in most cases has been confined to the first growth. There are several explanations for the severity of attack on the first crop, the most significant of which is the longer growing period, permitting the bulk of the eggs to hatch and nearly all of the larvae to attain full size. Another cause is the much greater spring egg-production, which results in larger larval populations than those attacking later growths. Injury to subsequent growths in 1953 was negligible, but in 1954 many instances were found where the "larval lag" was sufficient to seriously retard the second growth, where control was not undertaken.

In 1952, the heaviest destruction was localized along the west-central border of the State and in an isolated field near Smyrna; whereas, in 1953, severe injury was found east of Smyrna and moderate damage southward to Bridgeville and northward to Odessa. Only fields two or more years old were so affected, and no evidence of early spring infestation or damage was recorded in fields that were seeded the previous late summer or early fall. Severe spring losses occurred at many places on well-established alfalfa throughout the State in 1954. In spite of this, plantings less than 1-year-old were virtually free of infestation at the same time, except in one case where the damaged young field was adjacent to a heavily-infested planting that had been seeded 4 years earlier. Thus, if alfalfa is planted in such favorable locations for easy weevil invasion the following spring, injury may occur, but all surveys to date have indicated that isolated young fields ordinarily are not subject to such damage, and that they sustain no economic populations of adults until midsummer and of larvae until late summer or early fall.

Weevil Development.—Production of eggs occurs mainly in the spring, continues at a low rate through the summer, and again increases in August and with the approach of fall. They are laid in clusters, normally within the stems of the host plant, through a circular puncture which is usually sealed with bits of epidermis chewed from the stem, or with feces (Fig. 1). Sometimes, they are deposited promiscuously. No attempt has been made to study egg-laying throughout spring and summer under field conditions; however, clusters obtained in the laboratory in 1953 averaged larger in the spring than those laid late in the season. A detailed study was undertaken in October of that year, when 15 field-collected weevils were caged under outdoor conditions. Eggs were produced almost daily in clusters, ranging from 2 to 21 each, totaling 405, and averaging 9 per cluster. It is of particular interest to note that 146, or 35.6 per cent, were white when laid (in that respect resembling closely the eggs of the lesser clover leaf weevil, *Hypera nigrirostris* (F.)), and 261, or 64.4 per cent, the normal yellow. The incubation period in the spring (laboratory) was from 10 to 14 days, averaging 12 days. All of one cluster of 11 eggs, laid outside on October 7 and kept there, hatched after 19 days. A few, kept inside at 80° F., developed complete embryos, but eclosion never occurred because of attack by a common fungus discussed later.

Fig. 1.—Oviposition puncture and stem cut to expose eggs in cavity.

The egg stage is capable of surviving winter conditions in Delaware. This was ascertained in two ways; by exposing to outside conditions eggs that had been laid in the fall, and by dissecting others from field-collected stems in early spring. A total of 49 eggs that were deposited throughout October (1953) were kept outside under observation. Of these, 34 hatched during that month, and 15 remained unhatched through the winter. When the latter were examined in March of the following spring, three were still viable and hatched near mid-March, at about the same time initial hatching occurred in the field. As early as March 10, 90 field-collected stems were dissected. Three cavities containing viable eggs that had

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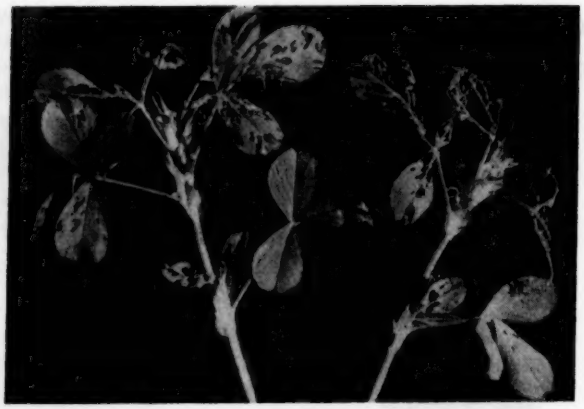

FIG. 2.—Injury by (third- and fourth-instar) larvae.

been laid the previous fall were found, as well as several in which there were only empty egg-shells, indicating that larvae had hatched from them before the onset of cold weather in early November. The first eggs laid by overwintered females were encountered in the field on March 18 (1954), after which egg production increased rapidly and was well underway by the first week in April.

While a few larger larvae (third instar) were obtained from field collections in mid-March (1954), indicating possible winter survival in this stage, more data are necessary to verify this point. Many first- and second-instar larvae were found in growing alfalfa tips during the second half of March and the first week of April at numerous places throughout the State; as many as seven per tip was not uncommon.

Under normal conditions, full-grown larvae spin cocoons prior to pupation. However, in small confinements with excessive moisture, cocooning may not occur, a phenomenon which does not seem to have been reported previously. The prepupal period, spent within the cocoon like the pupal period, required 2 to 3 days under laboratory conditions in the spring and the pupal period, 10 to 11 days. During midsummer, both are markedly reduced.

Adults from overwintered eggs emerged in the laboratory during the first week of April, and shortly thereafter under outside conditions. What appeared to be adults from eggs deposited in early spring began to issue abundantly in late April and early May. Overwintered adults have remained alive in laboratory cages throughout the summer. Therefore, three types of adults may coexist outside through the season; namely, overwintered, those from overwintered eggs, and large proportion from the current season's eggs. Adults are expecially active at higher temperatures, disperse from one field to another, and are attracted to lights in June. Unexpected decreases in adult populations, in fields that were heavily infested with larvae, are believed to be due to this type of movement to locate more suitable plantings, and to their ability to hide in debris, alfalfa crowns and within the hollow terminals of stubble in the original fields. This observation is not entirely in accord with the view of Hamlin *et al.* (1949), who maintain that, "despite a large migration of weevils, the fields producing large populations tend to retain large populations."

Newly-emerged females require a diapause before they can reproduce. This phenomenon was realized by several American workers prior to the investigation by Yakhontov (1934), who believed that a period of approximately 2 months, at a temperature range of 12° C. to 25° C., was necessary for maturation of the ovaries. While it is true that a few larvae can be located in late June and July, field collections for the past two seasons have revealed a noticeable small increase in August and a larger one in September-October. These increases are here interpreted as distinct divisions of a second generation, and may be designated as broods 1 and 2. It is possible that brood 1 is the product of adults from overwintered eggs, while brood 2 includes the off-spring of females developed from eggs laid the current season. In either case, it appears that only a relatively small proportion of the females produce fertile eggs during the season in which they emerge.

POPULATION TRENDS.—Observations on the bionomics of the weevil were so fragmentary in 1952 that no comparisons on behavior can be made with that of the following 2 years.

The technique for sampling populations was standardized throughout the two seasons being compared, with the exception of that used to obtain population counts in the 1954 experimental control plots (*c.f.*). Twenty-five sweeps were made at each of five sites per plot (1953 experiment) or field on every sampling date, using a sturdy, 15-inch beating net. After each series of 25 sweeps, the insects were removed from the net with an aspirator, tabulated, and placed in containers for transfer to the laboratory where their identity was rechecked. There are obvious limitations to this sweeping method. For example, tiny larvae may not be taken in proportion to their actual abundance, because they occur in situations that make them less accessible, in contrast to the more exposed, larger instars. Also adult collections may not be strictly representative, since live specimens are quick to perceive movement and may drop to the ground before the collector is within reach; in addition, it is a well-known fact that proportionately fewer adults are captured on cool, wet, dull, or windy days, when they prefer to remain near the ground.

Weather in 1953 was unlike that of 1954, and the weevils responded differently to this factor in the two seasons. Spring was advanced in 1953, but was followed by cool, wet conditions throughout May; precipitation was below average during the summer and temperatures fluctuated widely; the fall was unusually mild and much prolonged. In 1954, spring conditions were about normal, followed by drouth and very high temperatures until the first week of August; during the fall, precipitation was below normal and there were lengthy periods with temperatures below and above average.

The 1953 population trend in a 3-year-old field is plotted in figure 3. Larval abundance reached its peak during the first half of May and was on a decline before the middle of the month. Alfalfa was then in partial bloom, almost 2 weeks before the first cutting was made. This natural decline, after alfalfa had attained that degree of maturity, was noted on several occasions throughout the season. Hamlin *et al.* (1949) attributed the

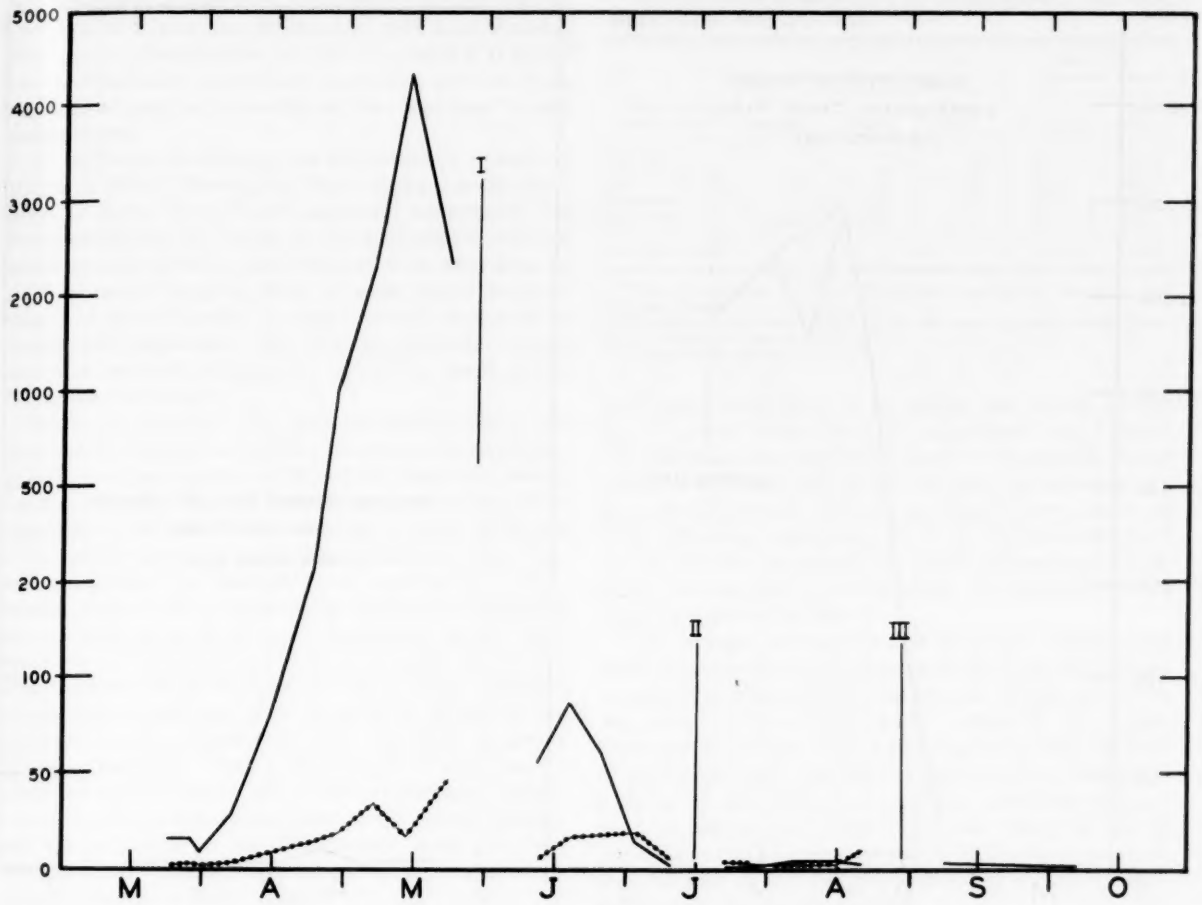

FIG. 3.—Population per 125 sweeps in a three-year-old field, 1953. Solid line, larvae; dotted line, adults. I, II, and III refer to cutting dates.

decrease to mortality of newly-hatched larvae deprived of suitable food, *i.e.* the lack of succulent growing tips. There is no doubt that the first cutting interferred with the normal decline, and that it reduced the larval population. Few larvae could be located in stubble shortly after the hay had been raked. The rise that occurred in the first week of June is interpreted as nothing more than a "larval lag" and/or the result of the hatching of eggs in stems or stubble that remained after the hay had been removed. There was no indication that the first new adults had as yet completed their diapause. Possibly, the decline shown in June really approximates what would have been the end of that begun in May, if the alfalfa had not been cut. The outstanding feature of the adult curve is that it shows an increase lagging behind the larval trend. There was no significant rise in population in this field between the first and second cuttings.

A study from July to September (1953), of old fields at various locations, showed an increase in population during August (Fig. 3). In all probability, this rise did not represent a new generation of normal magnitude, but rather brood 1 of the second generation.

In May (1953), two large cages were placed in a 3-year-old field at Newark for the purpose of detecting the appearance of a second generation. Only new adults from eggs laid the current season were introduced. In spite of an almost ruinous infestation of potato leafhopper, *Empoasca fabae* (Harr.), in June, July and August, the plants in one cage began to show some larval injury in September, indicating that a portion of brood 2 of the second generation had developed, even on unfavorable plant growth.

It has been mentioned that in June numerous adults, most of which appeared to be new, invaded and established themselves in plantings seeded the previous late summer or fall. A study of three such fields, in widely separated localities in 1953, provided the following information on population. In the southernmost field (Hartly), a peak was reached in mid-July. The second field, near the center of the State (Smyrna), allowed to reach a mature condition, had two peaks in August, followed by a decline that extended into September. The break between the two August peaks, while not especially low, normally should not have been apparent. Unfavorable weather when the sample was taken, or a drop in egg-production, might explain this situation. Adults were rather plentiful in August (1953). The magnitude of the larval peaks was nowhere near that of the spring peak

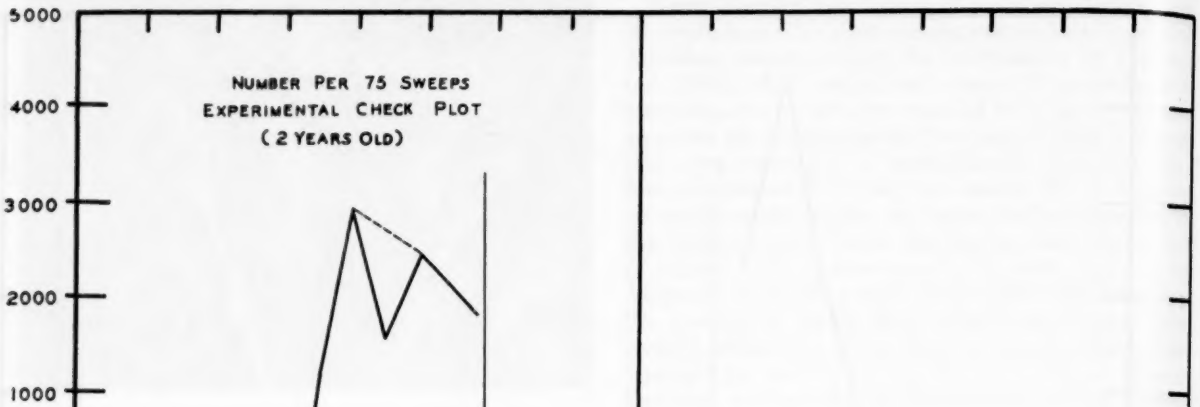

FIG. 4.—Combined larval and adult population per number of sweeps indicated, 1954.

in older fields. However, it is interpreted to indicate part of a second generation. The height of any second-generation peak should be less, if only a portion of the new adults produce eggs during the season in which they emerge. In the northernmost field (Newark), the third cutting was made about mid-September; and, from then until late October, both plant condition and ideal weather induced heavy egg-production by new females, resulting in a high larval build-up of what is interpreted as brood 2.

Larval samples collected in the field in 1953 were segregated into two categories, *i.e.* first and second, and third and fourth instars. Small larvae were more abundant in April, early August, and probably in late September and early October, although no samples were analyzed then. The peaks for older larvae—May and June, late August and October—support the contention that a second generation, consisting of what may be regarded as two separate broods rather than a second and partial third generation, is more plausible.

Tremendous larval populations occurred generally on the first growth in all well-established, older stands in 1954. Most of the counts at that time ranged from 0 to 37 larvae per sweep, and one severely infested field averaged near 50 larvae per sweep. The peak of larval population was reached during the latter part of April, a week earlier than in 1953, and began to decline shortly thereafter (Fig. 4). This decline progressed slowly through May and, at most places, was sharply reduced following the first cutting in early June. At a few locations, the "larval lag" was sufficiently great to cause injury to new growth, but in general larvae remained scarce throughout the season (Fig. 4). Surveys at frequent intervals from July 13 to October 7, inclusive, using the same sampling technique as in the previous season, emphasized weevil scarcity. Fifty-three visits in all were made to the various fields during this period. On approximately 40 per cent of these visits, no specimens were obtained. Larval populations in infested fields ranged from 1 to 18 per 125 sweeps, averaging 6; adults from 1 to 40, averaging 7; and the total population per field averaged 8. From these data, it is evident that the apparent total weevil population was very low throughout the season following the first cutting, a situation different from that in 1953 when larvae could be obtained easier during the summer and fall. Population counts, taken in four fields of various ages, are plotted in figure 4. A well-defined second generation was not as obvious as in 1953, except in certain younger fields where conditions were especially

favorable for its expression. A higher population was detected on two occasions in one such field near Smyrna. The counts at that location are shown in table 1. It should be noted that these increases in population were less than one-third as great as those at about the same time the preceding season.

The difference in summer and fall population trends in 1953 and 1954, following the first cuttings, might have been due to the weevil's environmental adjustment, but it is more likely the result of the detrimental effect of severe dry, hot weather that extended from early June to the first week of August, 1954. At some favorable situations, the weevil, under the more normal conditions in August and September, was able to partially recover from this set-back and produce at least a small second generation (or broods).

CHEMICAL CONTROL.—In 1953, an alfalfa field of approximately 5 acres, east of Smyrna, was selected for applications of insecticides on March 28, when the growth was 4 to 6 inches high. The field was divided into three equal plots. The center one served as a check, while one of the side plots was sprayed with dieldrin, and the other, with toxaphene. The materials were applied by a weed-control sprayer that delivered 25 gallons of liquid per acre at a pressure of 40 p.s.i. Population counts were made after 24 hours and at weekly intervals, thereafter, until the first cutting on May 28. The results, expressed as per cent control are given in table 2. Injury in the check increased progressively, and was rated as severe by the cutting date. That in the toxaphene plot was retarded for about 2 weeks, after which it increased until it became nearly as apparent as that of the check. Feeding was not noticeable in the dieldrin plot until the third week prior to cutting, and never became more pronounced than to be rated as light.

On June 4, 1953, a second test was made on the stubble. This was identical with the first, except that a different weed-control sprayer of similar capacity was used. The same series of counts were taken until the time of the second cutting on July 3. The population on the second growth was insignificant compared to that on the first. Percentages of control are given in table 3. Dieldrin was toxic to adults for about 4 weeks (Table 2). Control was less in the second test which was directed mainly against the larvae.

A third test was made on June 4, 1953 in a nearby 6-acre field, using Perthane on 3 acres and leaving the remainder as a check. Population counts showed no significant differences between treated and untreated sections.

In 1954, replicated plots (with each replicate 0.6 of an acre) were established in an alfalfa field about 2 miles distant from where the 1953 experiment was located. The materials were applied on April 7 with a weed-control sprayer at the rate of 33 gallons of spray per acre and at a pressure of 40 p.s.i. Population counts were taken 48 hours following treatment and, at weekly intervals, for 7 weeks; the 48-hour count, too small to be of any significance, was not used in the analysis. The results of other counts are shown in table 4.

The average per cent control with both dieldrin and heptachlor was high and approximately equal. Toxaphene averaged less than 50 per cent control. When malathion was added to these toxicants to control the pea aphid, there appears to have been a lessening in the effectiveness of heptachlor and, possibly, of dieldin. Conversely, the addition of malathion to toxaphene raised the average per cent control from 44 to 64 per cent. Since the use of insecticides on the second growth in 1953 proved unnecessary because of the low population, no control was attempted on this growth in 1954.

Percentages of control with dieldrin and toxaphene were higher in tests the first year than in those of the second. Possibly, this was due to the operation of such factors as weather and a heavy infestation of aphids in 1954.

Yields were determined by harvesting a green sample from 100 square feet in each plot; these were dried, weighed and converted to an acre basis. The differences in yields are shown in table 5. It should be noted that the yields from each of the different treatments is virtually proportional to the control obtained.

NATURAL CONTROL.—Thousands of specimens of the

Table 1.—Weevil population per 125 sweeps on dates indicated in a 1-year-old field. Smyrna, Delaware, 1954.

DATE	NUMBER OF		TOTAL
	Larvae	Adults	
July 27	4	3	7
August 17	16	0	16
27	5	8	13
September 30	18	3	21
October 7	8	1	9

Table 2.—Alfalfa weevil control on first growth, Delaware, March 28 to May 28, 1953.

TIME AFTER APPLICATION[a]	TOTAL POPULATION[b]			PER CENT CONTROL[c] WITH	
	Dieldrin	Check	Toxaphene	Dieldrin	Toxaphene
One day	0	8	0	100.0	100.0
One week(s)	0	29	0	100.0	100.0
Two	1	80	16	98.7	80.0
Three-four	8	636	217	97.7	63.0
Five-seven	1,112	4,559	4,007	80.5	23.9
Average Control				91.9	59.8

[a] Rate of application—dieldrin, 1½ pts./acre (4 oz. actual); toxaphene, 1 qt. 60% emul./acre.
[b] Number of larvae and adults taken in 125 sweeps on each sampling date; adults averaged 1.4 per cent of total.
[c] Computed by Abbott's Formula.

Table 3.—Alfalfa weevil control on second growth, Delaware, June 4 to July 3, 1953.

WEEKS AFTER APPLICATION[a]	TOTAL POPULATION[b]			PER CENT CONTROL[c] WITH	
	Dieldrin	Check	Toxaphene	Dieldrin	Toxaphene
One	7	59	13	88.1	78.0
Two	31	101	114	69.3	0.0
Three	12	76	73	84.2	3.9
Four	6	32	48	81.2	0.0
Average Control				80.7	20.5

[a] Rate of application—dieldrin, 1½ pts./acre (4 oz. actual); toxaphene, 1 qt. 60% emul./acre.
[b] Number of larvae and adults taken in 125 sweeps on each sampling date; adults averaged 13 per cent of total.
[c] Computed by Abbott's Formula.

Table 4.—Alfalfa weevil control on first growth, with dieldrin, heptachlor and toxaphene, Delaware, April 7 to May 27, 1954.

Weeks After Application[a]	Total Population[b]				Per Cent Control[c] with		
	Dieldrin	Heptachlor	Toxaphene	Check	Dieldrin	Heptachlor	Toxaphene
Without malathion							
One	7	5	22	38	81.5	86.8	42.1
Two	28	9	195	383	92.6	97.6	49.1
Three[d]	135	168	545	983	86.3	82.9	44.6
Five–seven	235	231	550	922	74.5	74.8	40.3
Average Control					83.8	85.5	44.0
With malathion							
One	8	9	10	38	79	76	74
Two	36	87	158	383	91	77	59
Three[d]	288	220	318	983	81	78	68
Five–seven	475	465	855	922	74	75	54
Average Control					81	76	64

[a] Rate of application:—dieldrin, 1¼ pts./acre (4 oz. actual); heptachlor, 1 pt./acre (4 oz. actual); toxaphene, 3 pts. 60% emul./acre; and malathion, 1½ pts. 57% emul./acre.
[b] Adults average 0.7 per cent of the total population taken in 25 sweeps.
[c] Computed by Abbott's Formula.
[d] Data for fourth week, obtained during cold, rainy weather, are omitted, since they are not indicative of the actual larval population.

different stages were scrutinized in 1953 without evidence of parasitism or predatism. One dipterous parasite, of unknown identity, emerged from a weevil pupa collected in 1954. On May 7, 1954, 260 adults of *Bathyplectes curculionis* (Thom.), presented through the courtesy of the Entomology Research Branch, U. S. D. A., were liberated at a favorable location 2½ miles north of Bridgeville, Delaware; whether this parasite is now established has not been determined. At present. therefore, it is impossible to predict the effect of such controls on the abundance of this pest. It is of interest to note that, in the same field where the 1954 control experiment was performed, large flocks of bobolinks were observed in May, apparently attracted there by the abundance of alfalfa weevils on which they are known to feed.

One of the most-common natural enemies of the weevil on the East Coast is *Beauveria globulifera* (Speg.) Picard, material of which was identified by Dr. Paul L. Lentz of the United States Department of Agriculture. This fungus has been reported by Charles (1927) and Steinhaus (1949) as a parasite of a long list of insects. It has been investigated by Petch (1926), Lefebvre (1931) and others. Destructive attacks on this insect in the West were noted, many years ago, by Rockwood (1916) and, recently, by Hamlin *et al.* (1949).

In Delaware, it infected weevils in the field under humid conditions throughout the season of 1953, especially during parts of May and June when many dead adults were observed. In most cases, the fungus growth was conspicuous, or could be induced to develop into characteristic form by keeping field-collected specimens under moist conditions. The presence of *B. globulifera* in nearly all laboratory cages, during that year, was the chief cause of weevil mortality. With high humidity, it destroyed as much as two-thirds of the population. It attacks all stages, including the exposed egg. Some preliminary tests were made, using first- and second-instar larvae as one group and the third and fourth as another, placed on plants in cages. Both were sprayed with fungus inoculum, while checks were treated with distilled water. Mortality in the inoculated cages ranged from 63 to 100 per cent, compared with 17 to 29 per cent in the checks. The older instars were more severely affected. This fungus was relatively unimportant in 1954; consequently, no observations or experiments were undertaken.

Summary.—The alfalfa weevil was observed first in Delaware on April 17, 1952, and has since spread rapidly throughout the State. Although the adult is the principal stage in which it passes the winter, the species can survive this period in the egg and, possibly, in the larval stage. The unusual weather in 1953 encouraged early-spring activity but the peak of larval population occurred somewhat later than in 1954. The first adults were produced in April and they continued to appear until very late fall. Overwintered adults were still present in small numbers toward the close of the season. Dispersal of adults to young alfalfa (less than 1 year old) occurred from June on. Prior to that time, the weevil and its injury were absent from such plantings in 1953 but, in 1954, did occur in one case where conditions were favorable for early spring invasion. The more suitable conditions in young fields throughout the summer and fall, irrespective of cutting

Table 5.—Increased yields from the use of insecticides against the alfalfa weevil. 1954.

Insecticides[a]	Pounds per Acre Over Check[b]
Dieldrin	392
Heptachlor	370
Toxaphene	218

[a] Without malathion (see Table 4).
[b] Yield of untreated check—2420 pounds per acre.

dates, favored the expression of a second generation, comprising possibly two broods; whereas, older fields appeared to be less likely to sustain any pronounced new generation.

This pest was not generally destructive in Delaware until the 1954 season. Heaviest damage was evident on the first growth in May, and was usually confined to fields 2 or more years old that previously had been infested.

An early-spring application of dieldrin in 1953 gave satisfactory protection to the first growth. Control with this material and with heptachlor on the first growth was also effective in the 1954 experimental plots. No treatment was necessary on the second growth. Yields were substantially higher in plots where control was attained.

No important parasites have been reared in Delaware from any stage of the weevil, and no predators have been observed. In 1953, a fungus, *Beauveria globulifera* (Speg.) Picard, caused heavy mortality, both under field conditions and in the laboratory, where preliminary tests showed that it can be 100 per cent effective. The same fungus was relatively unimportant in 1954.

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The Asiatic Oak Weevil in Delaware[1]

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The Asiatic oak weevil, *Cyrtepistomus castaneus* (Roelofs), is indigenous to Japan and was described by Roelofs (1873) from that Country as *Myllocerus castaneus*. Reitter (1900) recorded it from Siberia. The first North American specimens were taken at Montclair, New Jersey, in July, 1933 (Davis 1935). Since that time, it has become abundant and widespread in New Jersey (Soraci 1940, 1941; Weiss 1940, 1941) and in Maryland (Bissell 1953, 1953a). It has also been reported from Washington, D. C. (Bissell 1953), New York (Weiss 1940), around Charleston, West Virginia (Dorsey 1953; Craig 1953), Northampton County, Virginia (Matheny 1954) and Pennsylvania (E. L. Sleeper *in litt.*).

The first record of its occurrence in Delaware was a specimen taken at Newark on October 4, 1950, by H. E. Milliron; and the first indication of its potentialities as an economic pest was reported by Milliron, when he observed adults feeding heavily on several kinds of oaks near Harrington on July 30, 1951. In 1951, this insect was one of the more conspicuous and abundant species encountered in a survey of insects associated with red and pin oaks (Bray & Triplehorn 1953). Consequently, the 1953 and 1954 seasons were devoted to a study of its habits and life history under Delaware conditions.

The weevil has been recorded from all three Delaware counties as follows: Wilmington, Newport, Newark, Glasgow, Red Lion, Delaware City, Middletown and Townsend in New Castle County; Bombay Hook Wildlife Refuge, Dover, Wyoming, Willow Grove, Petersburg, Canterbury, Felton, Thompsonville, Hollandsville and Harrington in Kent County; Ellendale State Forest, Milton and Bridgeville in Sussex County. Greatest numbers were observed in a swamp forest on Bombay Hook, where almost every oak was severely damaged. Surveys show that it is decidedly more prevalent in New Castle County and northern Kent County, becoming less abundant as one proceeds southward in the State. The southernmost record is Bridgeville in Sussex County, where specimens were taken on peppers on August 8, 1954.

DESCRIPTION.—*Egg.*—The egg is smooth and glossy white when first laid, becoming yellowish in color within 24 hours. It is elongate-elliptical in shape, usually slightly curved with the sides nearly parallel. Fifty eggs selected at random from the bottom of oviposition cages measured 0.487 to 0.622 mm. (av. 0.554 mm.) in length and 0.285 to 0.370 mm. (av. 0.332 mm.) in width.

Larva.—The full-grown larva (Figure 2) is white, except the head, distal half of the penultimate abdominal tergite and the last abdominal segment which are yellow-

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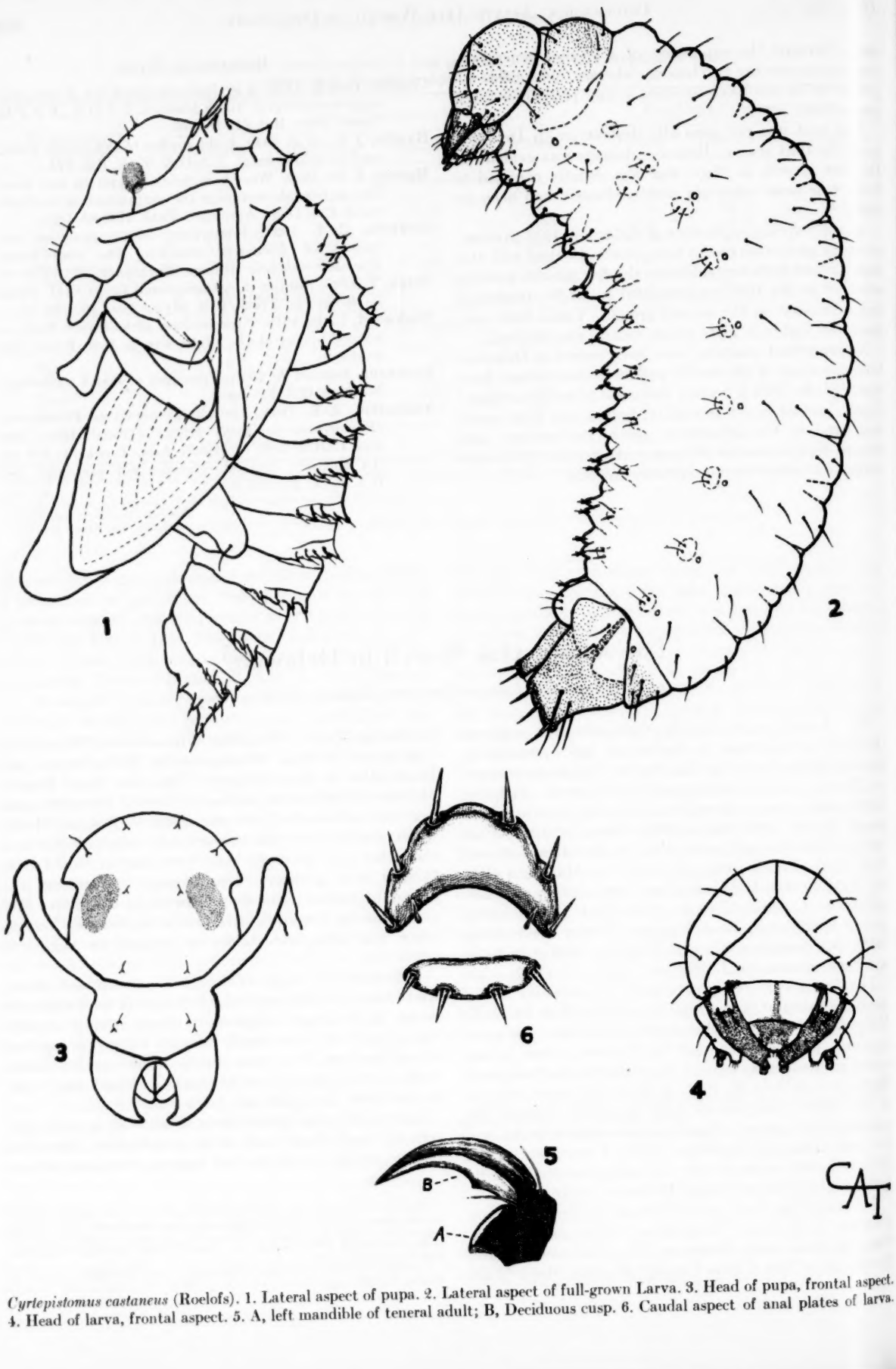

Cyrtepistomus castaneus (Roelofs). 1. Lateral aspect of pupa. 2. Lateral aspect of full-grown Larva. 3. Head of pupa, frontal aspect. 4. Head of larva, frontal aspect. 5. A, left mandible of teneral adult; B, Deciduous cusp. 6. Caudal aspect of anal plates of larva.

ish, and usually there are traces of yellow on the dorsum of the pronotum. The mandible is reddish-brown, darker distally and along the outer margin, with a pale subquadrate basal area. The clypealiae are reddish-brown, the epistomal suture darker; the clypeus and labrum are pale, except for a reddish-brown, median streak extending from near the fronto-clypeal suture, widening along the labral suture and forming, on the labrum, a more-or-less trapezoidal area terminating in two dark spots. The palpi are reddish-brown; those of the maxilla, somewhat darker.

There are 20 setae on the head, exclusive of the mouthparts: 10 on the epicranium, six on the genae and four on the frons (Figure 4). There are two at the base of each mandible, and 16 on the labrum, of which 12 are marginal. Lateral rows of rather uniform, coarse setae arise from the dorsal segments of the body, and setae of various lengths are borne in pairs on lateral protuberances. Ventrally, there is a transverse row of trifid setae on each abdominal segment. Long, conspicuous, simple setae are found on the venter of the first three body segments.

The relatively-large last abdominal segment is truncate distally, with the tergite angulately produced anteriorly along a median lateral carina, and terminating dorsally in a strong arc (Figure 6) of seven distinct, reddish-brown, setiferous lobes (except the mid-dorsal one), and ventrally as a weaker, smooth, reddish-brown, nonsetiferous arc; the much smaller sternite is transverse distally above, and slightly arched below with four, weak, setiferous lobes. This last segment bears in all 18 setae as follows: four lateral (two on each side along the carina), four transverse mid-dorsal, and 10 terminal.

Twenty-three final-instar larvae measured 4.8 to 6.3 mm. (av. 5.7 mm.) in length.

Pupa.—The extremely delicate pupa (Figure 1) is yellowish to white. Reddish-brown setae, arising from chalazae, are present as follows: Head—a pair on each side of the rostrum near the epistomal suture, a larger one on each side above these, a pair between and slightly above the middle of the eyes, a pair at the center of the vertex and one much longer seta above each eye and in line with the pair on the vertex. Thorax—six prominent setae in a row across the cephalic margin of the pronotum, eight setae forming a trapezoid in the middle of the mesonotum, and a similar group of eight on the metanotum. There is a long prominent seta at the apex of each femur. Abdomen—each segment has six to eight setae in a row across the posterior margin; the last segment terminates in two long, slightly divergent, stiff spines each bearing a small seta near the base.

The lateral margins of the pronotum are projected forward into a prominent lobe. The antennal club is narrowly fusiform.

Pupae range in size from 3.7 to 6.0 mm. (av. 5.4 mm.) in length.

Adult.—The adult is black to dark reddish-brown, irregularly clothed with minute green scales, which have a metallic lustre and are easily rubbed off. To the unaided eye, these cause the insect to appear greenish-gray. Each elytral interval bears a single row of long, erect, reddish-brown setae, as well as numerous, grayish-white, recumbent ones. The antennae are dark reddish-brown at the base, becoming lighter distally; the scape is slender, slightly curved, and reaches to the middle of the pronotum. The funicle is slightly longer than the scape, and the densely pubescent club is narrowly fusiform and pointed. The pronotum is coarsely punctured and subcylindrical, being widest at the middle with the sides feebly arcuate. The elytra basally are wider than the pronotum and have obtuse, distinct humeral angles. The legs are light reddish-brown; each femur is armed at its widest portion with a small, sharp, ventral tooth.

The average length of 50 field-collected adults was 5.8 mm. (maximum 6.7 mm.; minimum 5.1 mm.).

The deciduous mandibular cusps (Figure 5, B), characteristic of all Otiorhynchinae, to which this species belongs are conspicuous on teneral adults, but are lost soon after the insect emerges from the soil and their points of attachment are indicated only by pronounced scars.

SEASONAL LIFE CYCLE.—There is only one generation of this insect each year in Delaware. The overwintering stage has not been determined, but all evidence points toward the early larval stage. While it is true that overwintering adults may be recovered from leaf litter in midwinter, these probably contribute nothing to succeeding generations. Specimens taken as early as May 10 by sweeping foliage appeared very much weathered, and presumably were of the previous year's generation. Although supplied with an abundance of food, they did not feed and died soon after capture.

The first larvae were found on March 5, near Newark, by systematically digging around the roots of a small white oak seedling. These were collected from 5 to 6 inches beneath the surface litter, and ranged in size from 2.5 to 3.2 mm. in length. Weekly diggings throughout April and May produced greater numbers, but larval growth at this time was immeasurably slow. By April 23, they had migrated to a position 1 to 2 inches below soil level, where they remained until pupation. From the middle of May to the first week in June, the growth rate was greatly accelerated. Measurements of larvae taken on June 11 ranged from 5.4 to 6.3 mm.

Pupation begins around June 15, reaches a peak about July 10, and lasts until almost August. In the laboratory, the average length of the pupal period for eight specimens was 8 days, the minimum being 6 days and the maximum, 11 days.

Adults began to appear in numbers as early as June 18. They first attacked seedling oaks and often completely defoliated these by the end of June. Gradually, population pressure forces them to larger trees. The peak of abundance and of resulting damage to forest trees is attained about the last week in July.

During July, the number of weevils to be found on trees other than oak was insignificant; but, beginning with the first week in August, they became increasingly abundant on other trees, shrubs, rank weeds and even cultivated crops such as corn, peppers and beans. Laboratory tests indicated that they do not feed to any appreciable extent on any of these. At the same time, they began coming to lights. This positive phototropism reached a peak about August 25, when hundreds could be found on windows and walls of the Agricultural Hall at the University of Delaware, Newark. It often causes

consternation by invading houses in great numbers, somewhat in the manner of the boxelder bug. The latest record for both seasons was a single individual found on a clothesline on October 25.

The weevil is parthenogenetic. This had been suspected for quite some time but had never been proved. More than 300 individuals were dissected in 1953 without the recovery of a single male. Virgin females reared from pupae in the laboratory produced eggs from 13 to 18 days after emergence. All attempts at hatching these, or any other eggs produced during the course of these studies, resulted in failure. Ovipositon of caged females occurred first on July 12 in the 2 consecutive years and continued until July 28, in 1954, reaching a peak around July 20. Several field-collected females continued to oviposit up to August 20 in 1954. Parthenogenicity in the otiorhynchine weevils, is not an unusual phenomenon. Several individuals lived in laboratory cages for as long as 36 days.

Eggs are usually dropped singly; however, one mass of adherent ones contained eight eggs. Several attempts to determine the number of eggs deposited by individual females failed, but an examination of the ovarioles of 58 females revealed a minimum of 13 and a maximum of 76 fully-developed eggs per female. Gravid females were taken from July 6 to September 15.

FEEDING HABITS.—*Cyrtepistomus castaneus* appears to be a rather general feeder, but damage to the oaks far exceeds that to any other host. At the present time, it appears to be especially detrimental to seedling oaks. As such, the manifestations of these attacks may not become apparent for a number of years. Attacks on larger trees is usually not obvious until later in the season, at which time the trees would be much morel ikely to recover.

The nature of the feeding is quite characteristic and is easily distinguished from that of other defoliators, except *Calomycterus setarius* Roelofs, a closely-related weevil which attacks a larger number of hosts than *C. castaneus*.

The latter species is diurnal, is most active during the morning hours, but does not feed readily in strong sunlight. These weevils chew from the edge of the leaf toward the midrib, consuming everything but the larger veins and, if only a few are present per leaf, leaving the foliage in a very ragged and unsightly condition. They are often gregarious and may be found in large numbers under the curled edges of leaves, leaves webbed together by spiders, leaf rollers and leaf tiers and in similar situations.

Observations as to host plants acceptable to the weevil show a decided preference for almost any species of oak, closely followed (if not actually exceeded) by chestnut. The name "*castaneus*" is certainly not indicative of the coloration of this insect, and it would not be at all surprising to find that chestnut is the preferred host. The few chestnut seedlings available to it in Delaware were badly damaged. E. L. Sleeper (*in litt.*) found it feeding on both oaks and chestnut in Japan. He also noted that it is not common there and does little damage to native trees. He presumed that natural enemies are keeping it in check.

HOST PLANTS.—The plants listed below were acceptable as food to the weevil. Species marked with an asterisk were fed upon both in the field and in the laboratory.

Large-toothed aspen	*Populus grandidentata* Michx.
Mockernut hickory*	*Carya tomentosa* Nutt.
Hazelnut*	*Corylus americana* Walt.
Eastern hophornbeam*	*Ostrya virginiana* (Mill.) K. Koch.
Beech*	*Fagus grandifolia* Ehrh.
Chestnut*	*Castanea dentata* (Marsh.) Borkh.
White oak*	*Quercus alba* L.
Post oak	*stellata* Wang.
Swamp white oak*	*bicolor* Willd.
Chestnut oak*	*Prinus* L.
Northern red oak*	*rubra* L.
Pin oak*	*palustris* Muench.
Scarlet oak	*coccinea* Muench.
Black oak	*velutina* Lam.
Southern red oak	*falcata* Michx.
Water oak	*nigra* L.
Willow oak	*Phellos* L.
Raspberry*	*Rubus* sp.
Black locust	*Robinia Pseudo-Acacia* L.
Red Maple*	*Acer rubrum* L.
Flowering dogwood*	*Cornus florida* L.
Red-osier dogwood	*stolonifera* Michx.
Corn (sweet)	*Zea Mays* L.
Black willow	*Salix nigra* Marsh.
Weeping willow	*babylonica* L.
Slippery elm	*Ulmus rubra* Muhl.
Tuliptree	*Liriodendron tulipifera* L.
Sassafras	*Sassafras albidum* (*Nutt.*) *Nees*
Spice bush	*Benzoin aestivale* (L.) Nees
Sweetgum	*Liquidambar Styraciflua* L.
Sycamore	*Platinus occidentalis* L.
Apple	*Pyrus Malus* L.
Black cherry	*Prunus serotina* Ehrh.
Redbud	*Cercis canadensis* L.
Alfalfa	*Medicago sativa* L.
Lima bean	*Phaseolus lunatus* L.
Grape	*Vitis* sp.
Pepper	*Capsicum annum* L.
Persimmon	*Diospyros virginiana* L.
Green ash	*Fraxinus pennsylvanica* Marsh.
Tomato	*Lycopersicum esculentum* Mill.
Maple-leaved viburnum	*Viburnum acerifolium* L.
Elderberry	*Sambucus canadensis* L.
Squash	*Cucurbita sp.*

SUMMARY.—The Asiatic oak weevil, *Cyrtepistomus castaneus* (Roelofs), introduced from Japan, has become abundant in New Jersey, Maryland, Delaware and adjacent states. Where it has become established, it causes severe damage as a defoliator of all species of oaks and several other forest trees, especially to the seedlings which are attacked in early summer. It has potentialities of becoming a forest pest of considerable magnitude; and, in autumn, causes consternation by invading houses in great numbers, somewhat in the manner of the boxelder bug.

This insect is parthenogenetic and undergoes a one-year life cycle in Delaware, probably overwintering as a young larva. The feeding habits of the larvae are unknown, but they are closely associated with the roots of seedling oaks where they may be found in April and May. They pupate about the middle of June, and the adults begin emerging in numbers about a week later.

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Two New Phosphate Insecticides for Cotton Insect Control[1]

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In the screening program for new insecticides for use on cotton conducted at the College Station, Texas, laboratory, the most promising new compound for control of the boll weevil, *Anthonomus grandis* Boh., found during 1953 was a benzotriazine derivative of an ethyl dithiophosphate known as Bayer 16259.[4]

Two series of field-cage tests were conducted with this compound in 1953. In each test it was applied as a spray in various concentrations at the rate of 15 gallons per acre. The first test was conducted in June at a time when boll weevils are relatively easy to kill with insecticides, and the second test in October when they are very difficult to kill (Rainwater & Gaines 1951). In both tests compound 16259 was considerably more effective than the toxaphene standard (Table 1).

Attention was next directed to the methyl homolog of 16259, or Bayer 17147 (a benzotriazine derivative of a methyl dithiophosphate).[4] It has been demonstrated that methyl phosphates and thiophosphates are usually more effective against boll weevils than the corresponding ethyl compounds (Ivy *et al.* 1953). Accordingly both of these compounds were tested in laboratory or field tests during 1954.

TESTS AGAINST VARIOUS COTTON INSECTS.—Laboratory or field-cage tests were conducted against various cotton pests. Boll weevils, cotton leafworms (*Alabama argillacea* (Hbn.)), flower thrips (*Frankliniella tritici* (Fitch)), and cotton fleahoppers (*Psallus seriatus* (Reut.)) were collected in the field. The other species were reared in the laboratory.

Tests with the spider mite (*Tetranychus tumidus* Banks) and the cotton aphid (*Aphis gossypii* Glov.) were conducted in the laboratory in the manner described by Gaines *et al.* (1950), the test period being 3 days. Flower thrips were tested by placing adults on sprayed leaf sections in microscope-slide microcages and examining them after 1 day. Eggs of the pink bollworm (*Pectinophora gossypiella* (Saund.)) were placed under the calyxes of green cotton bolls, and the bolls were sprayed with insecticide and examined for larvae after 10 days. The boll weevil, bollworm (*Heliothis armigera* (Hbn.)), brown cotton leafworm (*Acontia dacia* Druce), and salt-marsh caterpillar (*Estigmene acrea* (Drury)) were tested in field cages by the procedure described by Ivy & Scales (1950), and the cotton fleahoppers in laboratory cages by the procedure described by Ivy *et al.* (1953).

Table 1.—Per cent mortality of boll weevils sprayed with different concentrations of Bayer 16259 and toxaphene, field-cage tests 1953.

TREATMENT (POUNDS PER ACRE)	PER CENT KILL IN 5 DAYS	
	Test in June	Test in October
Bayer 16259		
2.0	—	96
1.0	100	74
0.5	97	33
.25	84	14
.125	75	13
.0625	41	—
.0312	12	—
Toxaphene		
4.0	—	54
2.0	66	31

Each compound was applied as a spray in various concentrations. From 300 to 400 aphids or spider mites and 60 to 100 boll weevils or cotton leafworms were used in tests with each concentration, and in the pink bollworm tests 40 to 50 green bolls were infested with 5 eggs each. Against the other species 30 to 60 insects were tested with each concentration.

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[2] Entomology Research Branch, Agricultural Research Service, USDA.
[3] Texas Agricultural Experiment Station.
[4] Furnished by Farbenfabriken Bayer, A. G., of Leverkusen, Germany.

Table 2.—Per cent net mortality of various cotton pests treated with Bayer 16259 and 17147 in laboratory or field-cage tests.

Insect	Pounds per Acre	Bayer 16259	Bayer 17147	Standard	
				Toxaphene	Parathion
Boll weevil	2.0	—	—	86	—
	0.5	100	100	—	—
	.25	90	100	—	—
	.125	88	89	—	—
	.062	60	86	—	—
Cotton aphid	0.5	100	100	—	100
	.125	100	75	—	84
	.062	95	20	—	43
	.031	12	—	—	—
Spider mite	0.5	100	97	—	—
	.125	100	73	—	92
	.062	100	71	—	84
	.031	98	46	—	72
	.015	96	23	—	10
	.008	59	—	—	—
Bollworm	2.0	—	90	58	—
	1.0	—	92	—	—
	0.5	—	54	—	—
	.25	—	45	—	—
	.125	—	0	—	—
	.062	—	5	—	—
Cotton leafworm	2.0	—	—	45	—
	1.0	100	96	—	—
	0.5	96	100	—	—
	.25	75	84	—	100
Brown cotton leafworm	2.0	—	—	100	—
	1.0	—	100	—	—
	0.5	—	100	—	—
Flower thrips	1.0	—	—	50	—
	0.5	—	—	22	—
	.25	—	100	6	—
	.125	—	94	—	—
	.062	—	80	—	—
Salt-marsh caterpillar	1.0	74	15	—	—
	0.5	14	3	—	—
	.25	23	12	—	30
Cotton fleahopper	1.0	—	—	100	—
	0.5	—	—	100	—
	.25	—	100	100	—
	.125	—	100	—	—
	.062	—	100	—	—
				DDT	
Pink bollworm	4.0	—	—	55	—
	2.0	—	81	48	—
	1.0	—	64	19	—
	0.5	—	45	—	—

The results of these tests are presented in table 2. It will be noted that compound 17147 was more effective against the boll weevil than 16259, but that the latter material was more effective against the cotton aphid, spider mite, and salt-marsh caterpillar. There was little difference in effectiveness against the cotton leafworm. The two compounds were not compared against the other insects, but 17147 compared favorably with the reference standard in each test.

The results against the pink bollworm appeared especially promising. Bayer 17147 was more effective at 1 pound per acre than DDT at 4 pounds. Since field control of the pink bollworm by DDT is thought to be brought about in part by killing the adults, other laboratory tests were conducted by releasing the moths on treated plants. Complete kill occurred within a few hours after they were released on the plants treated with 17147.

TEST OF RESIDUAL TOXICITY TO BOLL WEEVILS.—Certain compounds which have shown up very well in the laboratory have failed to measure up to expectations when tested under field conditions. This is especially true of volatile or unstable compounds, which lose their effectiveness soon after application (Mistric & Gaines 1954). A field-cage test was accordingly conducted during July and August to determine the residual toxicity of Bayer 17147.

During the 21-day period of this test the maximum temperatures were very high. More than 100° F. was reached on 9 days, more than 95° on 15 days, and more than 90° on 19 days. Spray applications of compound 17147 and toxaphene were made as in the previous tests, and the test was conducted in the same manner except that there was a delay of 3 or 5 days in placing weevils on certain plants. There were three replicates of each treatment. From 60 to 100 boll weevils were tested at each concentration and interval after spraying.

Results of this test are shown in table 3. At the 1-pound dosage the spray deposit of compound 17147 compared favorably with that of toxaphene when the weevils were released immediately, and at 0.25 pound per acre it appeared to be effective for 3 days. In similar tests conducted at cooler temperatures the 0.25-pound dosage was effective for 5 to 7 days.

FIELD TESTS AGAINST THE PINK BOLLWORM.—A pink bollworm infestation developed in river-bottom cotton fields in Burleson, Brazos, and Grimes counties late in the 1954 season. Rains in late July furnished sufficient moisture for the plants to put on new growth and set considerable fruit. A number of planters protected the cotton from pests and produced a late second crop. Most of the fields were sprayed regularly with DDT, but heavy infestations developed in untreated fields. This situation afforded an opportunity to test Bayer 17147 under field conditions for pink bollworm control late in the season.

Three dust treatments—10 and 20 per cent DDT and 5 per cent compound 17147—and a check, each replicated four times, were used in a small-plot randomized-block experiment. Each dust was applied early in the morning with a rotary hand gun at the rate of 15 pounds per acre. The first application was made on September 10, when about 7 per cent of the blooms were found rosetted. Six additional applications were made at approximately 5-day intervals until the boll weevil and bollworm infestations were extremely low (less than 1 per cent).

Infestation records were made by pulling 100 hard, speckled bolls from each plot at weekly intervals during the period September 16 to October 15 and examining them for worms. Each boll was cut for lint and seed examinations. Yield records were made on November 5

Table 3.—Residual toxicity of Bayer 17147 and toxaphene, against the boll weevil, as indicated by per cent mortality when weevils were caged on plants at different intervals after treatment.

Treatment (Pounds per Acre)	Immediately	After 3 Days	After 5 Days
Bayer 17147			
1.0	100	61	48
0.5	89	44	14
.25	87	49	12
Toxaphene			
2.0	57	16	15

Table 4.—Average per cent of injured bolls, number of worms in infested bolls, and yield in pink bollworm control experiment, 1954.

Treatment	Date Counted	Per Cent of Injured Bolls	Number of Worms per 100 Bolls	Pounds of Seed Cotton per Acre
Bayer 17147 (5%)	Sept. 16	11.2	15.0	
	24	7.5	8.0	
	Oct. 1	4.3	5.0	
	8	2.0	2.3	
	15	0.8	0.8	
	Av.	5.2	6.2	994
DDT 20%	Sept. 16	22.0	28.2	
	24	28.3	41.8	
	Oct. 1	32.0	48.3	
	8	19.3	24.5	
	15	17.3	21.3	
	Av.	23.8	32.8	852
10%	Sept. 16	16.7	26.0	
	24	24.0	33.8	
	Oct. 1	18.8	36.3	
	8	23.0	35.0	
	15	19.8	27.3	
	Av.	20.5	31.7	900
Check	Sept. 16	24.0	41.2	
	24	31.8	44.5	
	Oct. 1	35.5	69.0	
	8	30.8	47.0	
	15	33.5	52.8	
	Av.	31.1	50.9	919

and 22. The picking area was 0.04 acre. The percentage of injured bolls and the number of larvae in infested bolls and the yield are shown in table 4. Plots treated with compound 17147 had significantly fewer injured bolls than those treated with DDT, and the data were highly significant when compared with the check, but there was no significant difference between the DDT treatments and the check.

Five-pound samples were taken from each plot, ginned, and graded. There were no differences in grade or staple among the treatments or the check.

Aphids increased in the check and DDT-treated plots sufficiently to produce honeydew in amounts evident to the eye 2 weeks before termination of the experiment. By the time the experiment was terminated, differences in the appearance of the foliage were pronounced. The foliage on plots treated with compound 17147 was green and luxuriant and free of aphids, whereas that on the check and DDT plots was yellowish green to brown, indicating aphid damage. Aphid control with 17147 may have contributed to the increased yields obtained on the plots treated with this compound.

SUMMARY.—Bayer 17147, a benzotriazine derivative of a methyl dithiophosphate, appeared promising in laboratory tests against the boll weevil, cotton aphid, spider mite, bollworm, cotton leafworm, brown cotton leafworm, flower thrips, cotton fleahopper, and pink bollworm. The compound was effective against both pink bollworm adults and larvae, and in a late-season field-plot test gave much better pink bollworm control than DDT.

Bayer 16259, a benzotriazine derivative of an ethyl dithiophosphate, in laboratory tests was more effective than 17147 against the salt-marsh caterpillar, cotton aphid, and spider mite, but was less effective against the boll weevil.

The residual toxicity of Bayer 17147 was greater than that of toxaphene.

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Biology and Seasonal History of the Lone Star Tick in Northwest Arkansas[1]

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The lone star tick, *Amblyomma americanum* (L.), is the most important tick pest of livestock in Arkansas. It probably accounts for 95 per cent of the total tick population. This paper is a partial report of studies on the biology, seasonal history, ecology, and control of this species.

METHODS.—The engorged females were collected from cattle and dogs. Each was placed in a glass tube about 25 mm. in diameter and 4 to 6 inches in length for oviposition. Tubes used in 1952 and 1953 had one end sealed with a plaster of Paris plug. This plug was saturated with water as often as necessary to supply moisture. Tubes used in 1954 were sealed at both ends with one-hole rubber stoppers, the holes being covered with 90-mesh Saran cloth cemented on with Duco cement. These were used in humidity chambers maintained at 85 per cent relative humidity (Sacktor *et al.* 1948). Oviposition and

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Table 1.—Life cycle of the lone star tick, Fayetteville, Arkansas.

Periods	Days Duration
Incubation	25
Pre-feeding, larval	10
Larval feeding	4
Duration of larval stage after feeding	12
Pre-feeding, nymphal	10
Nymphal feeding	4
Duration of the nymphal stage after feeding	21
Pre-feeding, adult	10
Adult feeding	6
Pre-oviposition	8
Oviposition	11
	121

hatching were observed without disturbing the contents of the tubes.

Young chickens 4 to 6 weeks old were used for feeding the immature stages. Larvae attached when brushed from the tubes onto the body of the chicks beneath the wing. Nymphs attached when brushed onto a bird confined in a glass battery jar. These jars had the bottom removed and a fine mesh screen was sealed over each end with friction tape while the jar was being used. Two to 6 hours were allowed for attachment. It was found useful to debeak the chicks on which nymphs were fed to prevent them from picking themselves.

Adults were fed on a bull or a cow, but could not be induced to feed on chickens. The method used by Hooker (1908) was not entirely successful. Those which fed were seldom recovered. The data presented on the length of the adult feeding period is limited. Engorged larvae and nymphs were recovered in metal pans placed beneath hardware cloth cages in which the host chickens were confined. Newspaper placed in the pans made the removal of the manure easy. Many of the engorged forms would be found beneath the paper. However, some had to be picked from the manure. Engorged forms were held in the tubes previously described. As molting began, the number was obtained usually by removing and counting those that had transformed. Sometimes the number could be determined without removing them from the tubes. All the rearing was done in an open air insectary where conditions of temperature approximated that outdoors.

Biology.—Egg masses were obtained from 185 females over the period 1952 through 1954. Preoviposition, determined from engorgement to deposition, required on an average from 8 to 15 days. One female delayed oviposition until 40 days after collection. Usually oviposition began in about a week or slightly longer. The oviposition period averaged 11 to 12 days, with a maximum of 22 days. The incubation period averaged 25 to 27 days. Some required as long as 50 days. The hatching period varied from 3 to 18 days.

Over 46,000 larvae engorged, 33,000 of which completed feeding on the fourth day. Twenty-eight thousand of the larvae transformed to the nymphal stage, 20,000 doing so in 12 to 14 days. Of the 3400 nymphs fed, 2700 completed feeding on the third and fourth day. Twenty-three hundred molted to the adult stage. This period varied from 21 to 28 days, for 1600 individuals observed.

Overwintered nymphs were collected, fed, and observed to determine whether there were differences in the periods required as compared to those given above. Of the slightly more than 2000 observed, the feeding period of over 1800 was 4 days. Some completed feeding on the third day and all completed feeding by the fifth day. There was, apparently, a tendency for the feeding period to be slightly more concentrated at this time of the year, since some of those feeding in the summer required up to 7 days.

The time required for the overwintered engorged nymph to transform to the adult stage appears closely related to seasonal temperatures. Thus, there is a tendency for the adults to emerge together. Nymphs which completed feeding on April 19 required from 47 to 54 days to molt; those fed April 27, 39 to 46 days; those fed May 13, 26 to 30 days; those fed May 26, 19 to 24 days; those fed June 16, 16 to 21 days.

Six adults engorged on a cow in April, 3 taking 6 days and 3 others 7 days. One was observed to feed in 13 days in September. Efforts to feed adults and nymphs in late August and September have resulted in repeated failure. In the field, adults are not observed on cattle at this time although temperatures are equal to or higher than those occurring during the normal adult feeding period in the spring. Observation of this was also made on another tick species (Hunter & Bishopp 1911). Since temperature is apparently not the factor it is suggested that the decreasing day length is responsible for the cessation of feeding activity. Increasing or decreasing photoperiod has been shown to affect the activity of the American dog tick (Smith & Cole 1941).

Allowing 10 days prefeeding period between the stages, the life cycle from egg to egg may be completed in Northwest Arkansas in 121 days. (Table 1). Calculated on the basis of minimums for each period it would be possible to have the cycle complete in 95 days.

Seasonal Cycle.—Both unfed nymphs and adults over winter. Adult males have been taken from cattle as early as December 17. Males persist and increase in numbers on cattle for about 6 weeks before females are found. The earliest record of an engorged female was February 19. By early March both males and females were numerous on cattle.

Collection by dragging (Table 2) begins to pick up ticks in March. Adults are taken into early July. Nymphs are found from March into September with two peaks of

Table 2.—Number and stages of lone star tick collected by drags, 1951–53, inclusive. Fayetteville, Arkansas.

Month	Larvae	Nymphs	Adults	
			Male	Female
March	—	—	3	—
April	—	250	35	30
May	—	240	30	41
June	75	195	42	51
July	2,117	76	6	2
August	11,232	119	—	—
September	3,018	25	—	—
October	297	—	—	—

occurrence. The first peak comes in April-May and the summer peak occurs in August. Larvae have been taken as early as June 10 and as late as October 30, the peak occurrence coming in August. Larvae do not survive winter.

The only period when the lone star tick is not readily found in Northwest Arkansas is during the month of November and the first half of December.

SUMMARY.—The life cycle of the lone star tick, *Amblyomma americanum* (L.), may possibly be completed in a minimum of 95 days; an average cycle, in 121 days. The 6-day feeding period of the adult observed is apparently the shortest on record. This is of importance in recommending the application of insecticides on a regular schedule.

It is suggested that decreasing day length is the factor responsible for the cessation of activity of the nymphs and adults in late August and September.

The taking of adult males from cattle by December 17 and collection of larvae by drag as late as October 30, establishes the earliest and latest occurrence for the species in Northwest Arkansas.

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The Egyptian Alfalfa Weevil and Its Control in Southern California[1,2]

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The Egyptian alfalfa weevil, *Hypera brunneipennis* (Boh.), was discovered in the United States in April, 1939, at Yuma, Arizona, by Wehrle (1939, 1940). When first collected it was believed to be the alfalfa weevil, *Hypera postica* (Gyll.), but it was subsequently identified as *H. brunneipennis* (Boh.). Further surveys were undertaken immediately, and the weevil was found 1 mile north of Yuma, near Winterhaven, Imperial County, California. No other infested areas were found in Arizona or California at that time. A year later a small infestation was found at the University of Arizona Date Experimental Farm near Tempe, Maricopa County, Arizona (McDuffie 1941).

Despite efforts to restrict the further spread of this weevil in California (Mackie & Carter 1939), it was reported by Armitage (1949) as occurring in the Coachella Valley, Riverside County, and in the Imperial Valley, Imperial County, about 50 miles west of the earlier record in the Yuma and Winterhaven areas. Although all previous records in the United States were noted in extremely hot, arid areas, the weevil was discovered by Armitage in 1950 in relatively cool, humid San Diego County.

The native habitat of this weevil has not been definitely ascertained, but it is known to occur in North Africa, particularly in Egypt, and in Ethiopia, India, and Sicily. Because of the dearth of parasites in this region, Dietrick & van den Bosch (1953) reasoned that northern Egypt might not be the native habitat of this species.

The exact mode of entry of *Hypera brunneipennis* into the United States is not known. The most likely manner of entry, however, seems to be through the importation of date palm stock from Egypt to Yuma, since it is known that large numbers of the adult weevils estivate in protected places at the base of date palm offshoots (McDuffie 1941).

In Egypt *Hypera brunneipennis* is considered a minor pest infesting primarily Egyptian (berseem) clover (*Trifolium alexandrinum*). Wehrle (1939, 1940), in the initial discovery of this weevil, recorded it on fenugreek (*Trigonella foenum-graecum*) and alfalfa (*Medicago sativa*). McDuffie (1941) extended the host range by reporting it as occurring on "bur-clover" (*Medicago hispida*), hubam (*Melilotus alba-annua*), and "sourclover" (*Melilotus indica*).

Initial observations in the Imperial Valley in 1950 and 1951 indicated that *Hypera brunneipennis* apparently preferred clover to alfalfa. During these early surveys the weevil was found in abundance on roadside clover but was seldom encountered in alfalfa. In the spring of 1952, however, several alfalfa fields sustained considerable injury. Since 1952, the weevil has extended its range in the Imperial Valley, and an increasing number of fields have been damaged.

Hypera brunneipennis has spread rapidly over the southern California area. This rapid spread is undoubtedly associated with large-scale shipments of baled alfalfa hay from the Imperial Valley into other areas. At present the occurrence of this weevil is rather general throughout southern California, notable exceptions being the Blythe area of Riverside County and the Lancaster area of Los Angeles County. The only localities in which damage has taken place to date, however, are in San Diego County, where both alfalfa and clover are damaged, and in Imperial County.

Preliminary biological studies of *Hypera brunneipennis* indicate that the life history of this species and the damage it causes are similar to that of the alfalfa weevil, *H. postica*. Adult weevils estivate during the hot summer

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months and begin to appear in the fields in mid to late December. Some damage results from the feeding of adults on leaves or plant stems, but most of the damage takes place in the tender growing tip. Eggs are laid in the hollow plant stems, and the newly emerged larvae apparently attempt to feed for a short period inside the stems before making their way out the oviposition puncture and up to the growing tip. When abundant, the developing larvae may completely skeletonize plants over large areas. The mature larvae pupate in thin, oval, net-like cocoons which are usually attached to the alfalfa leaves, although they are frequently found attached to the litter on the ground.

The adult emerges from the cocoon in 1 to 3 weeks and after feeding for a short time seeks a suitable place to estivate, usually underneath loose bark on trees, under boards, in dense weeds, or in other protected spots. Estivating adults are frequently found in the alfalfa fields, but the mortality rate is apparently high in such relatively unprotected areas. The most severe infestations are usually located near better estivating quarters, around the edges of the fields. To date only the first two alfalfa cuttings have been injured, as estivation begins in April and practically all the adults have left the fields by late May.

Preliminary information indicates that there is only one generation of *Hypera brunneipennis* a year in the desert area. Michelbacher (1943) reported that *H. postica* has one generation in the warm inland valleys but may pass through several generations along the coastal areas of northern California. Sufficient studies have not been made in coastal areas to determine whether more than one generation of *H. brunneipennis* occurs in such localities.

As previously stated, this species thrives and does considerable damage to alfalfa and clover in extremely hot, arid areas and in relatively cool, humid areas. Although the ecological limitations of this pest are not known, it certainly poses a serious threat to the tremendous alfalfa- and clover-producing regions of central and northern California. Because of the increasing damage caused by this pest in infested localities and the potential threat to uninfested areas of California, the present studies were undertaken to determine effective and economical control measures.

MATERIALS AND METHODS.—The Egyptian alfalfa weevil is vulnerable to insecticidal control in either the adult or the larval stage (Russell & Barnes 1951). Hastings & Pepper (1949, 1951) demonstrated that adults of the alfalfa weevil, *Hypera postica*, can be controlled prior to oviposition. In many cases, however, the alfalfa grower in the Imperial Valley does not know whether his alfalfa will be subject to attack by the Egyptian alfalfa weevil until larvae appear. A further complicating factor is that frequently the pea aphid, *Macrosiphum pisi* (Harr.), must be controlled in early-season alfalfa. Under such conditions, for reasons of economy, applications should be timed to control both the pea aphid and the larvae of the Egyptian alfalfa weevil. For these reasons tests for control of both larvae and adult forms of *H. brunneipennis* were undertaken.

In these tests all the materials were applied to alfalfa as sprays. Treatments were replicated four or more times in each test, with test plots ranging in size from about 0.2 to 0.6 acre.

Weevil adult and larval counts were made by sweeping the plants with an insect net. The standard 180-degree sweep was used in all sampling, with the lower edge of the net dipping about 8 inches into the alfalfa during the sweep.

Sprays were applied at various concentrations and volumes by means of either a small self-propelled power sprayer equipped with a 10-foot boom, or a larger 100-gallon power sprayer equipped with a 15-foot boom and pulled by a tractor. Both sprayers were equipped with low-volume nozzles.[5] A broadcast-type spray application was used to attain uniform coverage of the alfalfa.

Eleven chlorinated hydrocarbons and six phosphate-containing materials were used in these tests as follows: aldrin, chlordane, Dilan, DDT, dieldrin, endrin, EPN, heptachlor, lindane, malathion, Metacide, methoxychlor, methyl parathion, NPD, parathion, Perthane, and toxaphene.

RESULTS.—*Test 1.*—This test was undertaken on March 4, 1952. Sprays were applied to alfalfa at the rate of 25 to 27 gallons per acre with a small power sprayer equipped with a 10-foot boom. Each treatment was replicated four times and each replicate plot was 20 feet wide by 100 feet long. The 10-foot spray boom was equipped with 11 nozzles, and the sprayer was operated at a pressure of 125 p.s.i.

Treatments were evaluated on March 6 and 10, 2 and 6 days, respectively, after treatment, by sweeping the alfalfa and counting the larvae collected in the insect net. The alfalfa was cut before further counts could be made. Results are summarized in table 1. In this test all the insecticides used gave good to excellent control. Of the chlorinated hydrocarbon insecticides, chlordane, Per-

[5] Teejet No. 4, hollow-cone spray nozzles; Spraying Systems Company.

Table 1.—Effect of insecticides on control of the Egyptian alfalfa weevil on alfalfa in the Imperial Valley, California, 1952.

MATERIAL	POUNDS TOXICANT PER ACRE	GALLONS PER ACRE	NO. OF LARVAE PER 20 SWEEPS OF NET		PER CENT REDUCTION FROM CHECK
			March 6	March 10	March 10
Spray Treatment March 4					
Chlordane	1.08	27	855	52	98.7
Perthane	0.98	25	135	67	98.4
Dilan	1.08	27	513	80	98.1
Methoxychlor	1.08	27	172	165	96.0
DDT	0.98	25	370	393	90.5
Toxaphene	0.98	25	1404	526	87.3
Parathion	0.24	25	937	618	85.0
Untreated	—	—	4791	4120	—
L.S.D. at 5% level between treatments only			349.6	226.5	
Spray Treatment March 19			March 25	April 10	
Chlordane	0.54	27	78	122	
Lindane	0.25	25	111	163	
EPN	0.23	23	86	175	
Dilan	0.54	27	94	220	
Methoxychlor	0.52	26	336	251	
Toxaphene	0.44	22	302	304	
Perthane	0.54	27	92	313	
DDT	0.48	24	274	315	
Malathion	0.50	25	74	415	
Metacide	0.27	27	160	447	
Parathion	0.24	24	214	491	
Untreated	—	—	1189	731	
L.S.D. at 5% level between treatments only			103	172	

thane, and Dilan gave outstanding control (98.1 to 98.7 per cent reduction from check), and methoxychlor gave excellent results (96 per cent reduction). Kills were obtained more quickly with Perthane and methoxychlor than with the other materials tested.

Results obtained with DDT, toxaphene, and parathion were good. DDT and parathion are promising in view of the fact that both materials are effective when used for pea aphid control.

Test 2.—This test was begun on March 19, 1952. Sprays were applied with the same equipment as in Test 1, at rates ranging from 22 to 27 gallons per acre. Each treatment was replicated five times and each replicate plot was 10 feet wide by 200 feet long.

Treatments were evaluated on March 25 and April 10 in a manner similar to that used in Test 1. Results are summarized in table 1. In this test the chlorinated hydrocarbon insecticides were used at a relatively low rate per acre, and the results obtained were not so good as obtained in Test 1, in which the materials were used at higher rates. Of the phosphate materials tested, EPN was superior to malathion, Metacide, and parathion, particularly in residual activity.

Test 3.—Spray treatments were applied on February 26, 1953. Each treatment was replicated four times and each replicate plot was 20 feet wide by 100 feet long. Sprays were applied with a small power sprayer at rates ranging from 25 to 32 gallons per acre. The 10-foot spray boom was equipped with 10 nozzles, and the sprayer was operated at a pressure of 125 p.s.i.

Treatments were evaluated on March 4, 10, and 16 by sweeping the alfalfa with an insect net. Results are summarized in table 2. In this test Dilan, Perthane, methoxychlor, and methyl parathion gave excellent reductions (92 to 97 per cent) 18 days after treatment. Parathion, Metacide, and malathion gave good reductions (81.2 to 87.5 per cent), but NPD gave poor results.

Test 4.—Spray treatments were applied to stubble alfalfa on February 21, 1953, in an attempt to kill adults of the weevil prior to oviposition. Sprays were applied with a power sprayer at rates ranging from 24 to 31 gallons per acre. The 15-foot spray boom was equipped with 15 nozzles, and the sprays were applied at a pressure of 125 p.s.i. Each treatment was replicated four times, and each replicate plot was 30 feet wide by 150 feet long.

The treatments were evaluated on March 4, 10, 18, and 24 by sweeping with an insect net and counting the weevil larvae collected. Results are summarized in table 3. It is apparent from the results obtained in this test that excellent preventive control can be achieved. Heptachlor, dieldrin, and aldrin gave excellent results, with reductions from the check of 97.8, 94.9, and 93.3 per cent, respectively. Toxaphene, endrin, lindane, and chlordane gave good reductions (88.9 to 84.5 per cent). DDT gave fair results, but the reductions obtained with Dilan and EPN were poor.

On March 26 yield records were taken from five areas (one untreated and four treated) on the basis of hay weights just prior to baling. Four records were taken from each replicate plot, and each record was based on the weight of the hay from an area 10 by 15 feet in extent. The total weights of hay from each area were as follows: untreated, 248 pounds; DDT-treated, 283 pounds; endrin-treated, 285 pounds; toxaphene-treated, 286 pounds; and aldrin-treated, 286 pounds. As a result of field variation, none of the hay weights from the treated areas were significantly better at the 5 per cent level than those from the untreated area.

Test 5.—Spray treatments were applied on March 19, 1954, to rapidly growing alfalfa about 6 inches high. Sprays were applied with a power sprayer at the rate of 23.6 gallons per acre, at a pressure of 150 p.s.i. The 15-foot spray boom was equipped with 15 nozzles. Each treatment was replicated four times, and each replicate plot was 60 feet wide by 100 feet long.

The treatments were evaluated 3, 5, and 11 days after application by making 25 sweeps of the insect net per replicate (100 per treatment) and counting the weevil adults and larvae. Results are summarized in table 4. In this test, even at the low rates of insecticide applied per acre, excellent control was obtained. Perthane at both rates used gave much better control at the end of 3 days than heptachlor or aldrin. At the end of 5 days, however, all the materials gave excellent results. Just prior to cutting the alfalfa on March 30, excellent control was still evident on the plots treated with heptachlor and the higher rate of Perthane (96.9 and 95.8 per cent reductions, respectively), and the lower rates of Perthane and aldrin were satisfactory (90.3 and 86.7 per cent reductions, re-

Table 2.—Effect of insecticides on control of the Egyptian alfalfa weevil on alfalfa in the Imperial Valley, California, 1953.

Material[a]	Pounds Toxicant per Acre	Gallons per Acre	No. of Larvae per 40 Sweeps of Net			Per Cent Reduction from Check March 16
			March 4	March 10	March 16	
Dilan	1.20	25	13	16	23	97.0
Perthane	1.60	32	2	5	24	96.8
Methoxychlor	1.50	30	15	17	33	95.6
Methyl parathion	0.24	29	28	44	60	92.0
Parathion	0.26	31	20	28	94	87.5
Metacide	0.25	32	31	39	114	84.8
Malathion	0.72	31	15	53	141	81.2
NPD	0.72	29	131	187	262	65.1
Untreated	—	—	481	484	751	—
L.S.D. at 5% level between treatments only			40	82	54	

[a] Spray treatments applied February 26.

Table 3.—Effect of insecticides applied to stubble alfalfa for control of adults of the Egyptian alfalfa weevil prior to oviposition, Imperial Valley, California. 1953.

Material[a]	Pounds Toxicant per Acre	Gallons per Acre	No. of Larvae per 40 Sweeps of Net				Per Cent Reduction from Check March 24
			March 4	March 10	March 18	March 24	
Heptachlor	0.43	25	2	3	4	22	97.8
Dieldrin	0.21	27	7	15	37	51	94.9
Aldrin	0.40	24	0	3	14	66	93.3
Toxaphene	2.70	27	7	16	64	110	88.9
Endrin	0.24	29	8	28	99	124	87.5
Lindane	0.53	31	4	15	66	140	85.8
Chlordane	0.89	27	7	23	71	153	84.5
DDT	1.40	28	20	86	304	261	73.6
Perthane	1.40	28	5	65	285	460	53.5
EPN	0.40	30	48	206	743	716	27.7
Untreated	—	—	72	341	1375	990	—
L.S.D. at 5% level between treatments only			14	40	110	127	

[a] Spray treatments applied February 21.

Table 4.—Effect of insecticides on control of Egyptian alfalfa weevil on alfalfa in the Imperial Valley, California. 1954.

Material[a]	Toxicant per Acre	Gallons per Acre	No. per 100 Sweeps of Net						Per Cent Larvae Reduction from Check March 30
			March 22		March 24		March 30		
			Adults	Larvae	Adults	Larvae	Adults	Larvae	
Heptachlor	1.1 ozs.	23.6	14	246	12	49	0	18	96.9
Perthane	1.75 lbs.	23.6	30	37	28	12	1	24	95.8
Perthane	0.88 lb.	23.6	70	55	18	16	4	56	90.3
Aldrin	1.1 ozs.	23.6	16	230	10	46	3	77	86.7
Untreated	—	—	52	729	14	705	1	577	—
L.S.D. at 5% level between treatments only				135		31		39	

[a] Spray treatments applied March 19.

spectively). On the basis of this test it appears that, when used for Egyptian alfalfa weevil larvae control, heptachlor and aldrin at 1.1 ounces per acre and Perthane at 0.88 pound per acre will give excellent and economical control.

SUMMARY.—The Egyptian alfalfa weevil, *Hypera brunneipennis* (Boh.), was discovered in the United States near Yuma, Arizona, in 1939. Since 1949, it has spread rapidly over much of southern California. This weevil thrives and damages both alfalfa and clover in hot, arid areas as well as in relatively cool, humid localities. Although the ecological limitations are not known, this pest poses a serious threat to the tremendous clover- and alfalfa-producing areas of California.

Preliminary biological studies have shown that the life history and habits of this weevil are similar to those of the more northerly located alfalfa weevil, *Hypera postica* (Gyll.). Adults of *H. brunneipennis* estivate over the summer months and begin to appear in the alfalfa fields in December. Larvae are most abundant from February to April. The most severe damage occurs to the growing tip of the plant, and when the larvae are abundant, they may skeletonize alfalfa plants over large areas.

Hypera brunneipennis adults and larvae appear to be highly susceptible to a large number of insecticides. When tested for control of larvae the following chlorinated hydrocarbon insecticides at the rates per acre indicated gave excellent control: heptachlor (1.0 ounce), aldrin (1.0 ounce), chlordane (0.5 pound), Perthane (1.0 pound), methoxychlor (1.0 pound), and Dilan (1.0 pound). DDT and toxaphene applied at the rate of 1.0 pound per acre, and lindane at 0.25 pound per acre, were effective, although the control, in general, was somewhat poorer than that obtained with the materials listed above.

Of the phosphate insecticides tested for weevil larvae control, EPN and methyl parathion (0.25 pound per acre) gave the most promising results and appeared to be somewhat superior to parathion (0.25 pound per acre), malathion (0.5 to 0.75 pound), and Metacide (0.25 pound). Results were poor with NPD at 0.72 pound per acre.

When applications were made to stubble alfalfa to kill the adult weevils prior to oviposition, the following materials at the indicated rates per acre gave weevil larvae reductions ranging from 98 to 93 per cent: heptachlor (0.43 pound), dieldrin (0.21 pound), and aldrin (0.4 pound). Toxaphene (2.7 pounds), endrin (0.24 pound), lindane (0.53 pound), and chlordane (0.89 pound) gave reductions ranging from 89 to 84.5 per cent. DDT (1.4 pounds), Perthane (1.14 pounds), and EPN (0.4 pound) gave only fair to poor results.

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Notes on the Inbreeding of House Flies[1]

ELIZABETH T. LICHTWARDT, WILLIS N. BRUCE, and GEORGE C. DECKER[2,3]

Genetic studies of the house fly, *Musca domestica* L., especially with respect to the inheritance of resistance to insecticides, have been hampered because of the lack of inbred strains. Apparently house flies are not easily inbred, for it has been our experience that with continued inbreeding they rapidly lose fertility, a condition which frequently results in the complete loss of one or more inbred strains.

By developing a technique which made possible the handling of up to two hundred single females per generation we were able to inbreed two strains through 10 to 16 consecutive generations of sibling matings. One inbred strain, IR-1, a selection from "DDT I" (also referred to in the literature as "D+") is highly resistant to DDT, the other inbred strain, IS-1, a selection from "Lab I," is susceptible to DDT. The heterozygous parent stock (DDT I) of the inbred strain IR-1 was likewise originally selected for resistance to DDT from the heterozygous parent stock of the Lab I strain. The genealogy of the parent stock strains was reported by Bruce (1950).

The methods which were used for inbreeding these strains are described in this paper, whereas the results of genetic studies on these two strains will be published as separate reports.

GENERAL CONSIDERATIONS.—*Type of mating.*—Sibling matings by single pairs were considered desirable but since all of the flies emerging in any individual rearing cage resulted from a single mating, it seemed unnecessary to isolate virgin females. To avoid overhandling of newly emerged flies during the first generations we used single females already fertilized in the stock cages, then as inbreeding progressed, to insure fertilization one or more males were added to containers housing individual females. This procedure might conceivably result in occasional mixed male parentage for eggs deposited in a single day by any given female. On the other hand, there is good reason to believe females seldom mate a second time. In tests where 20 red-eyed females mated with red-eyed males were housed in cages containing only dark-eyed males, mixing of sperm occurred in only two females. The other females produced red-eyed progeny throughout their life span. In another experiment susceptible females mated with susceptible males were likewise retained in a container with only resistant males throughout the remainder of their egg laying period. There were no resistant progeny produced in this experiment, which would strongly indicate no effective second mating with the resistant males. However, to partially compensate for any possible second matings, inbreeding was continued beyond 10 generations whenever possible and then continued intermittently as time permitted. Also, progeny from individual egg batches, though resulting from the same female, were always kept separate and were never combined.

Selection.—Although it is possible that selection for a second specific characteristic might partially nullify the effects of inbreeding to achieve homozygosity for DDT resistance, selection for fertility and hardiness was considered essential in the development of both strains. Such selection was deemed necessary because of two previous unsuccessful attempts at inbreeding when such selections were ignored. The total pupal count from each female was the primary criterion for choosing the next generation parents, and egg batches from each were collected over a period of 5 to 7 days.

In developing the IR-1 strain, it is worthy of note that although no effort was made to select for resistance beyond the parents of the first generation of inbreeding, this strain not only maintained the resistance of the parent stock (DDT I) but is now effectively a pure resistant strain. After inbreeding for 10 generations when 373 IR-1 females were given topical applications of DDT at dosages up to 15.2 μg DDT/fly, the mortality obtained in 24 hours was only 1.6%. It is possible, however, that the IR-1 strain was at this time more than the indicated 98.4% pure for resistance, since when 513 F_1 females obtained from crosses between the inbred resistant (IR-1) and inbred susceptible (IS-1) strains were tested at 15.2 μg DDT/fly, the mortality was only 0.7%.

More through good fortune than design it so happens that both of the inbred strains carry useful genetic markers. The inbred IR-1 strain is effectively pure for a single autosomal recessive character, a broken subcostal wing vein = "b." The susceptible inbred strain (IS-1) is apparently pure for darkly pigmented abdominal sclerites of unknown inheritance, the expression of which is more intense in the females. The two strains are also quite distinctly different as to eye color and general appearance but there is little variation among individuals within each strain.

Breeding method.—The general rearing technique employed is a modified Peet-Grady method (Anonymous 1946). All stages of flies are kept at 78 to 82° F. with variable humidity. Pupae from individual egg batches are collected and placed in pint-size paper cans equipped with wire screen lids and lined with moist paper toweling. The adult flies are fed daily condensed milk diluted $\frac{1}{3}$ with tap water in 19 mm. × 65 mm. cheesecloth-capped shell vials inverted on top of the screen. This method was devised for handling stock flies by W. N. Bruce (1949) and has been used in this laboratory for several years. At 4 to 6 days after emergence the individual females are anesthetized with CO_2 and transferred to specially designed pint breeding containers described below. The egg batches are collected daily for 5 to 7 days in 19 mm. × 65 mm. shell vials containing cotton plugs moistened with condensed milk diluted $\frac{1}{2}$ with tap water. These vials containing eggs are then capped with paper toweling and stored for 12 to 20 hours or until the larvae hatch.

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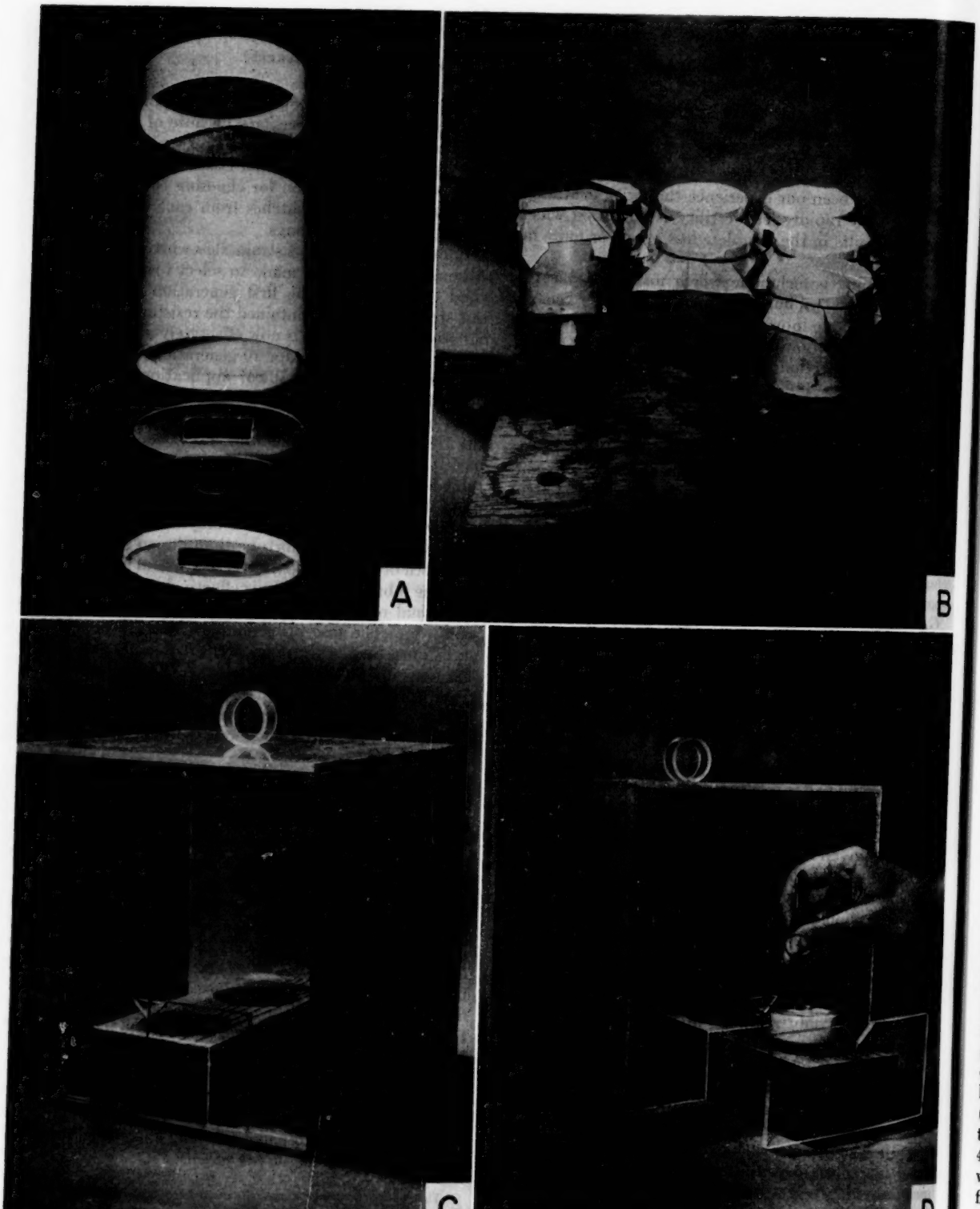

FIG. 1.—Equipment: (a) Parts of single pair breeding container; (b) Rack with 7 assembled containers; (c) Large plastic stock cage; (d) Stock cage showing method of inserting feeding dish into well.

The larvae in the cotton plugs are placed on a modified NAIDM medium in pint-sized Mason jars covered with paper towel lids. The formula for the medium is approximately 1,800 g. dry weight NAIDM medium to which is added 100 g. Brewer's yeast. The dry medium then is moistened with a mixture of 6,000 cc. water, 100 cc. dark Karo syrup, and 6 ounces of live bakers' yeast. The medium may be fermented for 12 hours before use, but this is not a necessity. One-hundred and fifty to 200 g. of the medium are added to each pint jar, the formula being enough for 40 to 50 jars.

Single pair breeding containers.—Pint paper cans, preferably the type with a false bottom, are used (Fig. 1a). The two bottom circles are removed and a 1½″ square is cut out of the centers. A rubber circle the same diameter as the can with a center hole measuring 19 mm. is inserted between the two cardboard circles and the three layers are stapled together. The bottom is then placed back in the can and the whole can except the lid is dipped in melted paraffin and then in cold water. The paraffin coating secures the bottom and enables the cans to be washed repeatedly. A wire screen is substituted for the paper circle in the lid and the cans are ready for use.

Individual females and several males are dropped into the bottom hole of the can and the vial for oviposition is then inserted half way into the can through the bottom hole, being held firmly in place by the rubber circle. A paper towel is then placed over the wire screen and secured with a rubber band. The paper cans are placed either on trays or special plywood racks (Fig. 1b), each rack holding 15 cans.

These pint paper cans are durable, washable, and if treated with care and occasionally rewaxed can be used for at least a year. They also are useful in handling flies for other purposes, especially when it is desirable to add flies to a container without having to remove the lid. For example, when collecting virgin females, repeated anesthetizing of the flies is unnecessary. When used in this way an empty shell vial is inserted upside down in the bottom hole and the flies are fed from the top through the screen.

The oviposition vials.—At the beginning of inbreeding it is not necessary to change the vials more often than every 2 days. As the flies decrease in viability, however, although the flies rarely lay more than once within a 36-hour period, the vials should be changed every day.

It is important to note that the cotton plugs should not be overly moist and should be placed in the vials at a slant. Otherwise, the fermenting milk may swell and drown the flies. On the other hand, the plugs should not be too dry or the flies may not feed properly. Tegosept-M (methyl parahydroxybenzoate)[4] proved to be very effective as a mold inhibitor when added in quantities of about 400 mg. to 400 cc. of condensed milk before dilution with water. Also, the addition of small amounts of powdered fly brei to the milk-soaked plugs increased the egg production of some of the less fertile strains. The fly powder is made by a modified method originally used by Dr. C. W. Kearns. Live flies are homogenized in acetone by means of a Waring Blendor, the acetone is filtered off and the remaining dry solid is frozen and stored for future use.

A method for checking genetic markers.—Since one of the markers, the "b" character, is too small to see without magnification we at first used ether as an anesthetic in checking the IR-1 strain. However, the ether appeared to cause a high rate of mortality and may have decreased the fertility of the flies thus exposed, and therefore we later used only CO_2 as an anesthetic for checking those flies from which eggs were to be collected. A small square box was devised as a gas chamber, having three sides of lucite, two sides covered by sheet rubber, and a removable lucite lid. Flies can thus be continuously exposed to CO_2 while being observed through a stereoscopic microscope.

Stock cages for the inbred strains.—As the pint breeding containers were too small for handling more than 50 pairs of flies, to prevent contamination stock cultures were maintained in special cages designed by W. N. Bruce for maintaining the inbred stocks in mass culture and for use in the production of mass genetic crosses (Fig. 1c). The cages are composed of four sides of lucite and two sides of wire screen. The only opening to each cage is filled with a sliding waxed wooden block containing two wells. Feeding dishes are inserted into the wells (Fig. 1d). The solid part of the block prevents any direct opening to the inside of the cage while the wells are exposed to the outside during feeding and restocking.

The cages are restocked by anesthetizing the flies briefly with CO_2, checking for contamination and the presence of stray eggs, and then dropping them in one of the wells. The quickest method for checking the genetic markers is to anesthetize and transfer the flies first to a pint breeding cage, using it in the same way as for collecting virgin females. The sorted flies then are reanesthetized and deposited in the back well of the service block. Then the egg-collecting dish is placed in the front well and the block inserted into the cage.

SUMMARY.—A method is described for raising house flies from a sufficient number of single females to insure continuation of an inbred strain. Methods for handling mass cultures of inbred strains are also described. Two strains have been successfully inbred through 10 to 16 consecutive generations by the use of these techniques. One inbred strain (IR-1) resistant to DDT carries a single autosomal recessive genetic marker, an incomplete or "broken" subcostal wing vein. The other inbred strain (IS-1) susceptible to DDT carries pigmented abdominal sclerites, the inheritance of which is unknown. Both inbred strains were selected for fertility alone during the inbreeding process, the resistant strain increasing in resistance, the susceptible strain maintaining its susceptibility to DDT. Each strain appears to be, in general, phenotypically homogeneous.

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[4] Recommended by Dr. James Crow, Department of Genetics, University of Wisconsin.

Increasing Complexities in the Apple Spray Program[1]

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In a recent publication Professor Paul Hudson, Dean of the Graduate School of Ohio State University, writes: "As the prospects are viewed, it is seen that research will be concerned increasingly with problems of complexity." That entomologists are concerned with the increasing complexity of their work goes without saying. More and more of our time and effort is used seemingly in the arrangement and coordination of facts so that the whole body of data may at least have the appearance of unity.

Entomologists who are charged with the preparation of spray schedules for use in their immediate area, are now faced with a full blown problem of complexities. This headache, which occurs as often as the spray schedule is rewritten and with after effects as the growers try to put it in operation, should at least receive the attempt of analysis. What are the factors in present day apple insect control that contribute to complexity?

There are many such factors and of these 10 are considered as playing the most prominent parts. These are being listed and discussed briefly as follows:

1. New Spray Chemicals.—Twenty years ago there were only three or four reliable insecticides for use in orchards. Today there are listed anywhere from 25 to 40 insecticides and acaricides plus many new fungicides, all of which may be used to advantage at certain times and under certain conditions. The entomologist and the grower must select from this list those that are to be recommended and used. This matter of choice, especially when one considers the slight differences in effectiveness that exist between many spray chemicals, is a matter of serious moment and frequently leads to much confusion. When we add to this the many unanswered or incompletely answered questions regarding varietal response, compatibilities (especially with new fungicides), phytotoxicity, possible off-flavors in fruits, accumulations in the soil, tolerances, and other legal aspects, etc., this factor alone assumes tremendous importance. The addition to our spray schedules of nutrient, thinning, and stop-drop sprays has not lessened the confusion. Also in considering complexities let us not forget the present day system of nomenclature. Fortunately, considerable improvement is being made in this field.

2. New Formulations.—Practically all of the new insecticides and acaricides are sold in many formulations. This is at times very convenient but it may be also quite confusing. For example, recommendations may be made on the basis of a 50 per cent dry wettable powder. All of us know the results when a 25 or 40 per cent product is used or when the grower not finding the dry wettable form tries to use an emulsifible concentrate. So far pelletilized materials have little part in the apple spray program but who knows how soon their use may add to the general confusion.

3. Price Differentiations.—The matter of prices, at least within certain limits, is not supposed to influence recommendations. However, the difference of a few cents a pound may be a deciding factor with the grower. He must seriously consider if the greater price will bring him corresponding benefits. Unfortunately, such results cannot be guaranteed. Lack of definite information on materials, seasonal conditions, expected crop prices, and other factors all add to the difficulties of actually evaluating the price factor.

4. New Machinery for Spray and Dust Application.—Since the end of World War II there have appeared on the market a tremendous number of new sprayers and dusters. We now have new model hydraulic sprayers, speed sprayers, concentrate sprayers, and mist blowers. They may be had with different abilities to perform different tasks, at different sizes, and at different prices. The grower must select one of these that will do adequate work but yet stay within a reasonable purchase price and operating cost range. These machines may be provided with many different systems of spray applicators, ranging all the way from the old fashioned spray rod to the fully automatic spray booms and heads. An entomologist may recommend a spray formula that will perform successfully in one machine but will be absolutely unsuited to another. New and varied machinery is a boon to the grower but may also be a source of great complexity.

5. New Methods of Chemical Treatment.—Some new methods are excellent while others may be only slightly better or even worse than the established procedure. When the entomologist recommends or the grower elects to use a new method, full data confirming the choice should be at hand. Otherwise many mistakes may be made. Examples of changes in methods are the spraying of tree trunks with DDT for peach borer control, weed control to prevent plant bug injury, and soil treatments for curculio and other soil inhabiting pests.

6. Different Recommendations.—Growers are frequently confused or alarmed by differences in spray recommendations that occur in adjacent or nearby states or by reports of results differing from those announced by their own particular agencies. This source of confusion could be largely eliminated by more cooperation between different research agencies in the announcing of results. Also a campaign to educate the growers as to the reasons for varying results in different areas might be well worth while.

7. Timing.—The accurate timing of spray or dust applications against insects is wonderful in theory and weak in practice. An entomologist may work out and execute very successful plans for timing spray applications against a few insects. Unfortunately, there are too many insects in too many places and all need attention. Therefore a successful program of timing is frequently abandoned after one or two seasons in order that other pests receive attention. Timing for the original insects is then done on a referable or remote control basis which all too frequently does not work. For example, the timing of sprays against plum curculio in Ohio is usually based on phenological observations. During the season of 1954, a spray schedule based on such phenomena failed to give control. Situations such as this are far too frequent and

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Table 1.—Codling moth control. Lorain, Ohio. 1954.

Plot No.	Materials[a]	Pounds per 100 Gallons of Water	Worms per 100 Apples	Stings per 100 Apples
1	DDT 50% (WP)	2.0	2.6	3.3
2	Parathion 15% (WP)	1.5	6.3	6.1
3	Diazinon 25% (WP)	2.0	3.7	7.7
4	Diazinon 25% (WP)	1.0	2.7	3.7
	DDT 50% (WP)	1.0		
5	Ryanicide 100	4.0	16.8	29.9
6	Ryanexcel 96-3	4.0	2.3	8.9

[a] Six applications.

Table 2.—Codling moth control. Cincinnati, Ohio. 1954.

Plot No.	Materials[a]	Pounds per 100 Gallons of Water	Worms per 100 Apples	Stings per 100 Apples
1	DDT 50% (WP)	2	94.6	34.7
2	Parathion 15% (WP)	1.5	8.1	7.8
3	Diazinon 25% (WP)	2.5	.9	7.3
4	EPN 27%	1	11.0	4.2
5	Ryanicide 100	6	4.7	16.4
6	Ryanexcel 96-3	6	3.3	14.2

[a] Eight applications.

tend to destroy the faith of the grower in much entomological information. Much more information than we usually possess about the insect and the season are needed for accurate timing. Every failure leads to more confusion and complexity.

8. INTRODUCTION OF NEW PESTS.—This is a very obvious factor that hardly needs expansion. All entomologists have had experience with introduced pests and are fully acquainted with the increased difficulties caused by them.

9. INCREASED DIFFICULTY IN CONTROLLING OLD PESTS.—In the sense that we wish to discuss this topic, it is distinct from that of resistance. The most notable examples of difficulty in controlling old pests have occurred where some marked change has taken place in the environment. For example, instances where the apple flea weevil has increased, have occurred when a change from clean culture to a sod-mulch system was made. Difficulty with the red-banded leaf roller became very common following the change from lead arsenate sprays to those of DDT. Other notable examples of this type are found among the mites, scales and aphids. The extension of the range of an insect may also cause much confusion. The apple maggot is a good example of this type of difficulty. Old pests, no matter how well they are controlled at present, all retain the potential of becoming a prime source of complexity.

10. RESISTANCE.—Resistance is not a new thing but its many appearances during the past few years, especially in connection with the use of new and highly effective insecticides, is a source of much concern. A further matter of interest is that at present representatives from all the major insect orders have developed this trait.

In Ohio two resistance problems of importance face the fruit grower. First, mite resistance to parathion and related compounds and second, codling moth resistance to DDT and lead arsenate.

Parathion-resistant mites were first suspected in Ohio in 1952, and this fact was proven by controlled experiments in 1953. During the 1953 season, about 15 orchards from all parts of the state showed evidence of resistant mite populations. During the past season (1954) many more orchards have reported failures in controlling mites with parathion. Spray schedules over a period of several years and including several applications of parathion each season have always preceded the appearance of resistance. This development has forced the abandonment of an effective spray schedule that included parathion in the pink and petal fall sprays. In this position in the schedule parathion was less expensive than other insecticides and acaricides and gave effective control of all pests. It also took the place of the early dinitro or oil sprays, thus effecting considerable savings for the grower. New schedules including other insecticides must now be written.

The extent to which resistance may develop is amazing. For example, in 1954 an orchard near Hamilton, Ohio, received a schedule of 10 successive applications of 15% parathion wettable powder at the rate of 1½ pounds per 100 gallons of water. In spite of this potent schedule, the European red mite developed to a point where every tree in the plot series showed definite mite injury with populations averaging over 20 mites per leaf. On the other hand, in an orchard at Wooster, Ohio, parathion has been used over a period of 6 years but only one or two applications per season have been made. In this orchard no evidence of resistance has appeared. It would seem that the prevention of resistance on the part of mites is largely a matter of limited use of any one acaricide.

Resistance on the part of the codling moth to lead arsenate is nothing new. Originally this problem drove over half of the commercial orchardists of Ohio to the use of DDT. In the past few years some growers have gone back to lead arsenate and a few others are using parathion. There are, however, numerous growers who have never used anything except lead arsenate for the control of codling moth. Resistance to DDT has been proven in experiments conducted during the past two seasons but as yet it occurs only in a limited area in southwestern Ohio. This has been shown by experiments and surveys in other sections of Ohio in 1954. For example, at Lorain in northern Ohio, a full scale field experiment with single tree plots replicated seven times gave results which are summarized in table 1.

These results were obtained in an orchard where codling moth is always a problem and where DDT had been extensively used for 9 years. Good control was obtained by a well timed schedule thoroughly applied. As similar results were obtained in other parts of the state, it is believed that increase in codling moth injury which occurred in 1954 was due to a season favorable to the insect rather than the general appearance of resistance.

On the other hand an experiment conducted in the orchard of the Hamilton County Experiment Farm, Cincinnati, Ohio, and arranged in the same manner as the experiment at Lorain gave the results summarized in table 2.

The tremendous differences in control are very obvious. Furthermore, preliminary counts made in late June, in July, and August fully confirm the data in the table which was taken in mid-September. As an additional check on the results all trees in plots 1 and 2 were scraped and banded in early June. These bands were examined and worms removed at frequent intervals during the summer months. The seasonal totals were:

From the DDT-treated trees	699 larvae
From the parathion-treated trees	5 larvae

These results plus those secured by the scoring of fruits, demonstrate the extent to which the codling moth in this orchard has developed a resistance to DDT after only 8 years of use. Opposed to this is the fact that no resistance is evident after 9 years of DDT usage in the Schmitkons Orchard at Lorain, Ohio.

SUMMARY.—The many factors that make for complexity are fully operative in most apple producing areas in Ohio. They render the formulation of a state wide spray schedule impractical if not impossible. The only remedy is to present to the growers a very flexible schedule which is little more than a list of suggestions with many alternate choices of materials, machinery, and methods of treatments.

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Fly Control in Dairy Barns in 1954[1]

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Beginning in 1952 phosphate insecticides were tested in New Jersey for control of house flies in dairy barns. Diazinon was one of the first materials tested, and it was reported as promising by Hansens & Bartley (1953). Since that time a number of other phosphates, including malathion, chlorthion, and Bayer L 13/59 have been tested by a number of workers as residual sprays. Several new methods of fly control by baits have also been developed. Thompson *et al.* (1953) reported on the use of a wet bait containing TEPP and sugar as a fly control treatment used on the barn floor. Gahan *et al.* (1953) reported further tests with this type of bait using a number of toxicants. Dry baits consisting of 1 per cent of a toxicant added to ordinary cane sugar were developed by Gahan, *et al.* (1954) while Bruce (1953) suggested use of a so-called varnish consisting of dark Karo syrup, Bayer L 13/59, and water applied to walls, ceilings, and various resting places of flies.

In 1954 it was decided to test new residual toxicants and several wet and dry bait formulations under practical field conditions in dairy barns in New Jersey. A portion of the program was set up in cooperation with the Geigy Agricultural Chemicals Company, and this work with Diazinon and Pirazinon is reported in a companion paper by Hansens & Scott (1955).

Nearly 50 barns, located in Salem County, in southern New Jersey, in Middlesex and Monmouth Counties in central New Jersey, and at Beemerville in Sussex County, were used in the studies. Malathion, Diazinon, chlorthion, Pirazinon, lindane, methoxychlor, American Cyanamid 4124 (0,0-dimethyl 0-(2-chloro-4-nitro phenyl) thiophosphate), and Penthion[4] were tested as residual sprays. Penthion wettable powder contained 10 per cent malathion and 30 per cent butoxy polypropylene glycol[5] and the emulsifiable concentrate contained 20 per cent malathion and 60 per cent butoxy polypropylene glycol. Malathion, Diazinon, chlorthion, Bayer L 13/59, and Pirazinon were tested as fly baits.

METHOD OF TREATMENT.—Barns used in the study were of various sizes and construction. In all but one or two, sanitation was good and fly populations were considered to be average for New Jersey conditions. Spray applications were made to all ceilings, walls, stanchions, and other exposed surfaces, using a single nozzle gun and a power sprayer operating at 150 to 200 pounds pressure. One gallon of spray was applied to 200 to 300 square feet of surface. Areas such as manure sheds, entry ways, and the like were also sprayed. Care was taken to cover feed troughs, water cups, and feed before spraying. Re-treatments of barns were made as necessary.

In locations where baits were used, either wet or dry baits were applied to floors in walkways and between the gutter and the feed trough. Baits were applied in front of feed troughs only under special conditions and when there was no danger of contamination of cattle feed. Dry baits were applied from salt shakers, sprinkling the bait sparsely over the area to be treated, and wet baits were applied from a sprinkling can in bands across the floor at intervals of 2 to 3 feet. Usually dry baits were applied at rates of 1 to 2 ounces to 1,000 square feet of floor space. Wet baits were applied at about 1 gallon per 1,000 square feet of floor space. Bait treatments were varied somewhat, depending on fly populations and the degree of control obtained with the bait.

SEASONAL FLY POPULATIONS.—This was an unusual year for fly control because of conditions and the appearance of a new fly problem. In previous years *Fannia spp.* were a problem only occasionally in dairy barns, but in 1954 they appeared in large numbers, particularly in central New Jersey. As one method of evaluating control

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[4] A product of S. B. Penick & Company.

[5] A product of Carbide & Carbon Chemicals Company.

measures, 10 sweeps with an insect net were made each week in 20 dairy barns in central New Jersey, and flies were identified. Numbers of flies taken were not large because all of these barns were under treatment with various residual sprays. Results of these studies are shown in table 1 and it is apparent that *Fannia* made up almost the entire fly population early in the season and then decreased in numbers, with a sudden drop in number at the end of July. The house fly, on the other hand, gradually increased in numbers, especially at the end of a long drought period late in August. During much of July and August there was very little rain, and breeding places for the house fly were reduced to a minimum, resulting in correspondingly low adult fly populations.

The high incidence of *Fannia* and the unfavorable breeding conditions for the house fly through most of the season make the interpretation of fly control data difficult.

EVALUATION OF RESULTS.—Fly control was evaluated by making three different counts at least 3 times each week. First, a fly index was determined by making a general observation and recording flies as scarce, few, fairly numerous, numerous, or abundant. Several different persons made observations during the season, but it was found that the index each selected agreed very closely in those instances when more than one person made observations in a barn at the same time. This was done several times during the season so that observations could be compared directly. Second, a stanchion count was made in each barn, and the number of flies resting on a group of three stanchions at each of two locations in each barn was recorded. Third, counts were made on Scudder fly grids (18 inches square) at 6 locations in each barn. Locations for counts were selected at random in each barn but at places where flies were most numerous, such as over gutters and in feed troughs. In the barns in central New Jersey 10 sweeps were made with an insect net twice a week for counting, and once a week the flies were retained for identification. In making the sweeps, 5 were made near the ceiling and 5 near the floor. At Beemerville, only stanchion counts were made through most of the season.

In evaluating control of residual sprays, counts for the 2 groups of 3 stanchions and the 6 grids were totalled. If the total count was more than 60, the insecticide under test was considered to have failed making it necessary to respray. In making the final decision concerning effectiveness of an insecticide, the fly index and net counts were also taken into consideration. Study of data showed there was a very high correlation between stanchion and grid counts, and a combination of the two counts seems to give a very acceptable method for measure of fly abundance in New Jersey.

With fly baits, it was more difficult to evaluate effectiveness since continued application of baits should result in progressively better control. Counts were made in the same fashion as for residual sprays, and totals were obtained on 6 stanchions and 6 grids. Usually five counts were made each week. From these counts two values were calculated: (1) the per cent of the counts where there were less than 20 flies on grids and stanchions, and (2) the average flies per day for the period of treatment. This average was derived by totaling all of the counts and dividing by the number of counts made. In evaluating effectiveness of control, it was considered that good control had been obtained only when there were less than 20 flies on stanchions and grids. On the other hand, an average of more than 60 flies on stanchions and grids indicated failure of the bait under test. A count of 60 flies was also used to indicate failure with residual sprays.

RESULTS WITH RESIDUAL SPRAYS.—The length of effective control for each residual spray treatment at each location is set forth in table 2 from which it is evident that there was a great variation in the effectiveness of a single material as well as between materials. These variations for a given material are due in part to variations in the seasonal fly population. Early in the season *Fannia*

Table 1.—Flies collected weekly in 20 dairy barns[a] in New Jersey. 1954.

DATE	FANNIA SPP.	MUSCA DOMESTICA	OTHER FLIES	TOTAL FLIES
June 18	95.1%	0	4.9%	374
June 26	94.0	1.4%	4.6	711
July 9	80.0	9.7	10.3	195
July 16	82.8	12.9	4.3	116
July 24	63.4	23.2	13.4	224
July 31	60.0	19.2	20.8	193
Aug. 13	23.7	32.4	44.1	34
Aug. 20	12.9	67.1	20.0	85
Aug. 30	2.9	77.1	20.0	35
Sept. 3	0.9	98.2	0.9	112
Total	74.7	16.2	9.1	2079

[a] Based on 10 sweeps of insect net in each barn.

Table 2.—Fly control from residual insecticides in dairy barns in New Jersey 1954.

INSECTICIDE[a]	AMOUNT PER 100 GALS.	BARN NO.	DATE TREATED	DAYS CONTROL
Methoxychlor 50%, W.	40 lbs.	1	May 31	51
Methoxychlor 5% W. +Crag[b] 50%, W.	20 gals.	1	Aug. 6	33
Lindane 25%, W.	8 lbs.	6	May 31	19
		6	July 15	9
		7	May 31	22
		7	July 15	6
		34	July 23	14
Malathion 57%, Em.	2 gals.+20 lbs. sugar	20	June 2	23[c]
		20	July 1	63
		21	June 2	16
		21	July 1	14
Malathion 25%, W.	40 lbs.+20 lbs. sugar	10	June 1	17
		10	July 2	12
		19	June 2	16[c]
		19	July 2	82[d]
		30	July 23	41
Penthion W.	40 lbs.	10	Aug. 6	20
Penthion Em.	2 gals.	21	Aug. 6	14
Chlorthion 25%, W.	16 lbs.	16	July 12	20
		16	Aug. 19	22
		7	July 27	38
		31	July 23	34
Amer. Cyan. 4124 50%, W.	16 lbs.	17	July 12	64
		32	July 23	46
	32 lbs.	6	July 27	49
Amer. Cyan. 4124 25%, Em.	2 gals.	33	July 23	41

[a] W. refers to wettable powder; Em. to emulsion concentrate.
[b] Butoxy polypropylene glycol.
[c] Barn re-sprayed because of *Fannia* spp; house flies not present.
[d] End of season and still giving control.

Table 3.—Results from use of baits for fly control in New Jersey, 1954.

Treatment	Ounces of Bait Used per 1000 sq. ft.	Barn No.	Date Applied	Per Cent of Counts Having Less Than 20 Flies	Grids & Stanchions Average Flies/Count
Dry Baits					
Malathion 1% on sugar	2	41	6/9 to 7/23	10	47
	4	41	7/27 to 8/27	36	31
	3	18	8/ 3 to 18	25	28
	1.5	46	6/14 to 9/30	0	92[a]
Malathion 2% on hominy grits (Ortho Dry Bait)	2.5	36	8/16 to 18	0	112
	3	36	8/19 to 23	0	128
	2.5	36	8/24 to 25	0	61
Malathion 1% (Fasco Fly Flakes)	2	40	8/12 to 27	9	27
Diazinon 1% on sugar	16	39	7/21	0	60
	8	39	7/22 to 8/2	0	59
	4	39	8/ 4 to 11	33	26
	2	40	6/29 to 7/10	11	40
	2[b]	40	7/13 to 19	0	36
	2	40	7/20 to 8/6	77	17
	1.5[b]	44	8/ 3 to 9/30	87	10
	1.5	47	7/ 1 to 15	33	46[a]
	1.5[b]	47	7/16 to 8/ 2	20	30[a]
	1.5	47	8/ 3 to 9/14	60	20[a]
Diazinon 1% on calcite (10% powdered sugar added)	8	39	8/20 to 27	20	29
Pirazinon 1% on sugar	2	38	6/ 9 to 24	15	47
	4	38	6/28 to 7/19	0	74
Bayer L 13/59 1% on sugar	2	42	8/ 2 to 27	11	38
Bayer L 13/59 varnish		35	8/13 to 27	0	61
Chlorthion 1% on sugar	2	38	8/ 3 to 27	88	11
Wet Baits	*Toxicant*				
Malathion 57% E.	0.3 oz.	42	6/ 9 to 7/19	0	71
	0.8 oz.	45	6/14 to 9/30	0	86[a]
Ortho M. (Malathion plus lindane)	1.6 oz.	36	6/ 9 to 24	45	19
	1.6 oz.[b]	36	6/28 to 7/7	37	39
Diazinon 25% E.	1.2 oz.	37	6/ 9 to 24	40	24
	1.2 oz.[b]	37	6/28 to 7/9	33	22
	No treatment	37	7/10 to 8/1	20	38
	Water only	37	8/ 2 to 10	43	21
Bayer L 13/59 Tech.	8 g.	43	7/28 to 8/27	9	62

[a] Stanchion counts only. Actual count on 6 stanchions doubled to equal stanchion plus grid counts.
[b] Three applications bait per week.

was the fly problem, and as indicated in the table, some barns were resprayed for *Fannia* control even though residual sprays have little effect on these flies because their habit of constantly hovering makes them less susceptible to residual sprays. Later in the season, dry weather and consequent low fly populations resulted in unusually long periods of effectiveness for the sprays.

Methoxychlor and lindane were included in the spray program where flies resistant to these materials appeared in 1952. With methoxychlor, control was obtained for over a month. Also, with a formulation of 1 per cent methoxychlor and 10 per cent butoxy polypropylene glycol control was obtained for a month. Lindane was applied in two barns where sanitation was superior at all times. The first application gave excellent results. However, by the time the second spray was applied, resistant flies had appeared, resulting in very little control.

Malathion in combination with sugar was tested as an emulsifiable solution and as a wettable powder. Both formulations gave 2 to 3 weeks of fly control, except in barns 19 and 20 where control for a much longer period was obtained because of the disappearance of the fly populations caused by dry weather. The penthion formulations of malathion and butoxy polypropylene glycol gave

results similar to those with malathion mixed with sugar.

A 0.5 per cent chlorthion concentration without sugar gave 3 to 5 weeks of fly control.

American Cyanamid 4124 was tested as a wettable powder at 1 per cent and 2 per cent and as an emulsifiable solution at 1 per cent concentration of the active ingredient. This material, applied in July, gave excellent control for 6 to 8 weeks. In one barn, application to a whitewashed surface resulted in the whitewash turning an undesirable yellow-green color. It is understood that such discoloration can be prevented by adding small amounts of a weak acid to the spray tank before application of the spray. Of the materials reported here, American Cyanamid 4124 gave best results, followed in order by chlorthion, methoxychlor, malathion, and lindane. There was no evidence in any of the tests of resistance of house flies to the phosphates, whereas control failed with the second application of lindane.

RESULTS WITH BAITS.—Baits were usually applied 5 times per week to areas where there was no cattle feed. Details of treatments with baits and results of the applications are set forth in table 3. Results, as noted above, are given in terms of (1) per cent of counts with less than 20 flies on 6 stanchions and 6 grids and (2) average flies on 6 grids and 6 stanchions during the period of treatments.

It is apparent that there was great variation in the effectiveness of various baits. Baits did not give results comparable to those obtained with residual sprays. In all instances, however, the baits reduced the fly population. There seems to be little difference in effectiveness between wet and dry baits except with Diazinon wet bait where pronounced residual effects were noted.

Malathion wet and dry baits were not as effective as baits with some other toxicants. With malathion, flies were kept to a fairly low level, but adequate control was not achieved. In our tests with dry baits, differences in fly populations between barns overshadowed differences between bait formulations prepared with sugar, hominy grits, or oyster shell.

Diazinon wet bait, used in only one barn, gave better results than any other bait. Control was achieved during the period of application, and for a month afterward there was only a moderate increase in flies. For the last week of this month when no bait was applied, water was sprinkled on floors, increasing the attractiveness of the remaining bait. Dead flies were found regularly through the entire period. Diazinon dry bait also gave excellent results. In Barn 39, an extremely high fly population was reduced by 90 per cent with a single heavy application of bait, and effective fly control was obtained after an additional 10 days of treatment. In the same barn, later in the season, a test with 1 per cent Diazinon on "barn calcite" with 10 per cent confectioners sugar added gave results equal to dry sugar bait. "Barn calcite" is used in barns to prevent slipping of cattle, and if fly control materials could be added to this material, the farmer would be saved one operation.

Pirazinon dry bait, used in only one barn where there was a low fly population, gave results inferior to other baits.

Bayer L 13/59 baits gave results similar to those with Diazinon dry bait. As a wet bait, it reduced flies rapidly in a heavily infested barn. From an average of nearly 200 flies before treatment, flies were reduced to an average of 87 during the first 11 days of treatment and to 37 for the second 11 days of treatment. The average for the entire period is 62, as shown in table 3. Bayer L 13/59 varnish, tested in one heavily infested barn, gave very rapid kill of flies, but not enough material was applied to give satisfactory control. This varnish bait was found undesirable because it became very sticky in humid weather.

Chlorthion dry bait, tested in one lightly infested barn, gave outstanding results. Fies were reduced in 2 days from an average count of 80 to an average of 10.

Diazinon wet bait gave best results, including residual kills for a month after treatments were stopped. Diazinon dry baits, Bayer L 13/59 wet and dry baits, and chlorthion dry bait gave excellent kills but no residual effect. Bayer L 13/59 varnish, Pirazinon dry bait, and malathion formulations were somewhat less effective.

It was evident that constant treatment is necessary with baits. In all treatments, a higher fly count was noted most Mondays after no treatments were made on Saturand Sunday. In general where a very low fly population was obtained by use of baits, treatments were still necessary every other day.

Baits, as now developed, gave only partial control of house flies and failed completely in control of *Fannia* and *Stomoxys*, both important pests in 1954. *Fannia* may not be a problem another year, but the blood-sucking *Stomoxys* is an important cattle pest, and certainly sugar baits will not give control.

Fly control can no doubt be obtained adequately and cheaply with baits in many situations. However, residual sprays have the advantages of more complete fly control, less frequent applications, and partial effectiveness against *Fannia* and *Stomoxys*. In our opinion, residual sprays are considerably superior to baits which are chiefly useful as adjuncts to residual treatments.

SUMMARY.—Residual sprays and wet and dry sugar baits were tested in dairy barns in New Jersey in 1954. The fly problem is discussed, including the appearance of *Fannia* spp. as a problem. Data are presented to show that in dairy barns in central New Jersey in 1954, *Fannia* spp. was the most abundant fly in June and July, whereas the house fly was the dominant species later in the season. Methods used in evaluating treatments are presented.

American Cyanamid 4124 was the best residual treatment here reported (see Hansens & Scott 1955), giving 6 to 8 weeks of control. Chlorthion, methoxychlor, malathion, and lindane were less effective in the order named. Of the bait treatments, Diazinon as a wet bait sprinkled on floors gave best results with about a month of control after actual treatments were stopped. Diazinon dry baits, Bayer L 13/59 wet and dry baits, and chlorthion dry bait gave excellent kills but no residual effects. Bayer L 13/59 varnish, Pirazinon dry bait, and malathion wet and dry baits were somewhat less effective.

Residual sprays gave results superior to those obtained with baits. Bait formulations are regarded as most useful as adjuncts to residual treatments. In some instances baits will give adequate and cheap house fly control, but they are not effective against *Fannia* or *Stomoxys*. Residu-

al sprays are at least partially effective against these pests.

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Control of the Onion Thrips in South Texas in 1954[1]

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During 1954, experiments were conducted to evaluate new insecticides, to test the effectiveness of the currently recommended insecticides, and to determine the time and number of applications necessary for commercial control of onion thrips, *Thrips tabaci* Lind., at the Winter Garden Experiment Station and at the Lower Rio Grande Valley Experiment Station.

PROCEDURE.—An insecticide evaluation experiment and a time of application experiment were conducted at the Winter Garden Experiment Station. An experiment, using airplane to distribute the insecticides, was also conducted in Zavala County. Experimental plots located at the Winter Garden Experiment Station were 1/180 acre in size and were replicated 4 times. Applications in the timing experiment were applied at 7-, 14- and 21-day intervals. Rate of spray applications for each test was 25 gallons per acre. The airplane application test plots were 20 acres in size. Sprays were applied at the rate of 4 gallons per acre.

Three experiments were conducted in the Lower Rio Grande Valley for the control of the onion thrips. High gallonage sprays were applied at the rate of 100 gallons per acre with a 3-gallon garden sprayer. Each plot was 1/70 acre in size and each treatment was replicated three times.

Records for all insecticide experiments, at the Winter Garden and the Valley stations, were taken by counting the onion thrips on 10 plants per plot at various intervals after a single application. The records for the timing experiment were made at 7-day intervals throughout the season after applications were begun. The percentage reduction in infestation was based on the thrips population in the untreated check in all experiments except the test treated by airplane. In the latter test, the initial infestation at the time of application was used because the leaving of check plots was impractical.

Table 1.—Control of onion thrips with insecticide sprays. Winter Haven, 1954.

TOXICANT PER ACRE IN 25 GALLONS OF WATER (LBS.)	DAYS AFTER APPLICATION		
	1	4	8
	Per Cent Reduction		
0.3 BHC plus 0.5 DDT	75	67	76
0.25 dieldrin	47	42	59
0.5 aldrin	34	9	37
0.5 heptachlor	35	40	50
2.0 toxaphene	14	17	52
0.1 methyl parathion	59	15	65
0.2 parathion	83	51	87
0.625 malathion	76	27	75

Table 2.—Control of onion thrips with sprays applied by airplane. Winter Haven, 1954.

TOXICANT PER ACRE IN 4 GALLONS OF WATER (LBS.)	UNTREATED CHECK[a]	DAYS AFTER APPLICATION					
		1	4	8	11	14	18
		Per Cent Reduction					
0.5 heptachlor	34	38	9	21			
0.28 dieldrin	57	12	0	12			
0.25 heptachlor plus 0.25 parathion	35	60	74	89	74	89	74
0.19 dieldrin plus 0.25 parathion	69	58	88	94	81	81	78
0.25 aldrin plus 0.25 parathion	32	53	88	91	63	72	47
0.25 heptachlor plus 0.19 dieldrin	11	36	9	0			
0.38 parathion	50[b]	34	94	90			

[a] Initial count of thrips per plant 1 day before treatment.
[b] Initial thrips population 3 days before application

RESULTS.—At the Winter Garden station, ground applications of parathion, malathion and BHC plus DDT gave good control of thrips on onions 1 day after application. Effective control of the thrips 8 days after application was obtained with parathion, BHC plus DDT, and malathion as shown in table 1.

In an airplane spray experiment, commercial control was obtained with parathion or mixtures including parathion as recorded in table 2. Heptachlor and dieldrin, alone or combined with each other, were ineffective.

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Five applications of 0.5 pound dieldrin per acre at weekly intervals was significantly better than three applications at 7-day intervals. Three applications at 7-day intervals, three applications at 14-day intervals and two applications at 21-day intervals gave equal results.

In the Lower Rio Grande Valley, the use of the following materials resulted in good to excellent control of the onion thrips 1 day after application: dieldrin, toxaphene, endrin, parathion, malathion, Diazinon, Pyrazoxon, methyl parathion, BHC plus DDT, and lindane. Satisfactory control 4 days after application was obtained in plots receiving parathion, malathion, methyl parathion, Pyrazoxon and BHC plus DDT. Good commercial control 8 days after application was obtained in plots receiving dieldrin, toxaphene, Pyrazoxon and methyl parathion (Table 3).

A comparison of results from the Winter Garden Experiment Station and the Lower Rio Grande Valley Experiment Station shows considerable contrast. Previous to 1954, control of thrips with organic insecticides had compared very favorably from both locations (Richardson & Wene, 1952). Dieldrin and heptachlor gave outstanding initial and residual control in 1952 and 1953 at Winter Haven (Richardson 1953, 1954). During the 1954 season, dieldrin, aldrin, heptachlor, toxaphene and methyl parathion did not effectively control the onion thrips in the Winter Garden area. In the Lower Rio Grande Valley the use of dieldrin, toxaphene, methyl parathion, BHC-DDT, and malathion resulted in good thrips control. Parathion, although effective in both areas immediately after application, did not show as good residual control in the Lower Rio Grande Valley as it did at the Winter Garden station.

Table 3.—Control of onion thrips with high volume sprays. Weslaco, 1954.

Toxicant per Acre in 100 Gallons of Water (Lbs.)	Days After Application		
	1	4	8
	Per Cent Reduction		
Test 1			
0.4 dieldrin	92		75
0.2 dieldrin	87		64
0.2 dieldrin+1 pint DuPont spreader-sticker	82		43
2.0 toxaphene	91		63
1.0 toxaphene	77		48
1.0 toxaphene+1 pint DuPont spreader-sticker	89		64
0.2 endrin	95		60
0.1 endrin	91		53
0.25 parathion	94		46
Test 2			
1.2 malathion	99	87	61
0.6 malathion	94	79	45
0.5 Diazinon	83	54	46
0.5 Pyrazoxon	84	74	64
0.25 methyl parathion	94	78	64
0.25 parathion	93	89	58
Test 3			
0.5 Diazinon	95	64	
0.25 Diazinon	95	44	
0.5 Pyrazoxon	88	26	
0.25 Pyrazoxon	87	34	
0.22 BHC+0.38 DDT	99	73	
0.11 BHC+0.19 DDT	90	17	
0.25 lindane	93	14	

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Large-Area Tests of a Male-Annihilation Method for Oriental Fruit Fly Control[1]

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The development in Hawaii of methyl eugenol as an outstanding lure for male oriental fruit flies, *Dacus dorsalis* Hendel, for scouting and population studies and the early stages of an experiment designed to control these flies by destruction of the male population have been described (Steiner 1952).

Males of all ages are attracted to methyl eugenol. In a large outdoor cage stocked with newly emerged fruit flies, a trap baited with methyl eugenol removed enough males before they became sexually mature to prevent 98 per cent or more of the females from becoming fertile.

Experiments in Opaeula Gulch.—Preliminary experiments were carried on in Opaeula gulch, which is located on Oahu on the western slope of the Koolau Mountains near their northwestern extremity, at elevations ranging from 1000 to 1300 feet. Forty-five open-face box traps were treated at 6-week intervals with a slurry of parathion wettable powder, on which 4 to 8 ml. of methyl eugenol was applied weekly (Fig. 1). These bait stations, when maintained along one rim of Opaeula gulch and one of its laterals, caught 2.2 million male oriental fruit flies during the first 13 months of their operation and killed many more. The infestation in ripe guava fruit in Opaeula gulch averaged 4.2 larvae per

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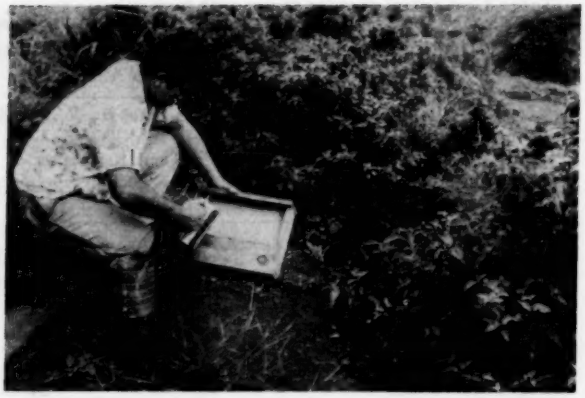

FIG. 1.—Original box-type feeding station, one of 45 in operation near Opaeula gulch. Flies consumed methyl eugenol applied over a parathion wettable powder film painted on the inside of the box.

pound, compared with 31.6 to 39.6 in four adjacent untreated gulches. Extensive but probably normal movement of the adult fruit flies, including fertile females, into the treated area was a factor preventing attainment of complete control.

In March 1951, after 13 months of operation, the bait stations were redistributed to provide better coverage in the direction of the prevailing trade wind. Forty were placed along opposite rims of a $1\frac{1}{2}$ mile-section of the previously used 300-foot-deep Opaeula gulch at approximately 400-foot intervals. Five were placed in the bottom of the gulch across an area of about 150 acres of guava, five more $\frac{1}{4}$ mile southwest, and five 1 mile northeast of the treated portion of the gulch, which is 1000 to 2000 feet wide at the rims. The bait stations were treated with the parathion slurry at 6-week intervals and with 6 ml. of methyl eugenol in a water emulsion weekly. After August the parathion was replaced by Pyrolan. This toxicant was dissolved in the methyl eugenol to make a 1.5 to 2 per cent solution, and approximately 10 ml. was applied biweekly.

Guava crops were produced from March to May and from June to October in 1951, and from February to May 1952, when the experiment was terminated. Infestations were determined in 3 to 5 samples of 50 guavas each collected 2 to 4 times monthly in the treated gulch and in each of 4 or more comparable surrounding gulches. The fruits were held over sand until all surviving larvae had left the fruit. Infestation indices were based on the numbers of living and dead larvae or pupae found in the holding boxes per pound of fruit in the sample.

During three crop seasons the monthly mean infestations in the treated gulch ranged from 55 to 100 per cent less than those in the untreated gulches, and averaged 87, 83, and 76 per cent less (Table 1). It has been found that when picked guavas of average size show infestations of 1.8, 4, 8, 20, and 42 larvae per pound, the respective percentages of fruit infested will approximate 10, 25, 50, 75, and 90. It can be reliably estimated, therefore, that from 20 to 85 per cent of the guavas produced in the untreated areas were infested, compared with less than 30 per cent in the treated gulch.

The 55 stations caught approximately 922,000 male fruit flies from March 1951 to May 1952. The five upwind stations nearest heavy guava-producing areas in the mountains caught 345,000 of these flies.

The preoviposition period of approximately 10 days under normal Hawaiian conditions gives the flies ample time for long-distance dispersal from points of their emergence. Probably because of this factor and the flight habits of the oriental fruit fly, there was seldom any significant relationship between the number of flies caught at the feeding stations and the local infestation indices. Many of the flies caught in the treated area were from outlying locations, including some from the untreated gulches. In an area of the size treated, suppression of the infestation to less than 15 per cent of that in surrounding areas may be impossible because of immigrant fertile females.

Although the Opaeula tests were conducted under various seasonal conditions, it is possible that some unknown local condition made Opaeula less favorable for fly breeding than the nearby untreated gulches and that the indicated control was not due to the destruction of males.

IMPROVEMENT OF FEEDING STATIONS.—In order to test the method with more isolation than was possible on Oahu, two experiments were started on the island of Hawaii in January 1952. Before and during these experiments efforts were made to improve the feeding stations.

Table 1.—Effect of male destruction on oriental fruit fly infestations in three successive guava crops. Opaeula gulch, Oahu, Hawaii, 1951–1952.

Compound Month	Number of Male Flies Caught	Average Number of Larvae per Pound		Per Cent Reduction in Treated Gulch
		Treated Gulch	Untreated Gulches	
Crop 1:				
March 1951	36,500	0.7	5.7	88
April	53,500	2.2	6.5	66
May	123,500	3.7	38.4	90
	Mean	2.2	16.9	87
Crop 2:				
June 1951	74,500	0	5.0	100
July	11,000	0	10.5	100
August	7,800	1.4	3.1	55
September	36,400	2.5	9.3	73
October	150,000	2.2	7.7	71
	Mean	1.2	7.1	83
No crop:				
November-January	333,500	—	—	—
Crop 3:				
February 1952	50,000	4.6	13.9	67
March	17,200	3.8	10.9	65
April	13,300	4.8	28.6	83
May	15,000	2.0	9.7	79
	Mean	3.8	15.8	76

FIG. 2.—A solution of Pyrolan in methyl eugenol being applied to Canec squares for oriental fruit fly control.

Tests were run on both the islands of Hawaii and Oahu with various absorbent surfaces and toxicants to determine the most effective ones for use on the stations. There were more than 40 replicated treatments, which captured nearly ¾ million flies. The Opaeula box-type station with methyl eugenol and parathion was no better than a fully exposed, unpainted cane-fiber insulation board (Canec), 10 by 10 by ¾ inch, treated monthly with 25 to 30 ml. of methyl eugenol containing 3 per cent of Pyrolan. Less than 3 per cent of this toxicant killed too slowly after 3 weeks of weathering in the most windy and rainy areas of the Hamakua coast. Flies feeding on month-old residues of this strength were paralyzed within 30 to 75 seconds and they died within 2 to 3 hours.

These tests also indicated that Pyrolan kills more flies than does technical or emulsifiable parathion, Diazinon, Pirazinon, dieldrin, lindane, or malathion. Feeding stations treated with this material also proved to be more attractive when the solution was spread over most of the Canec surface than when applied to less than half. It was also found that Canec squares fully exposed to rains of as much as 10 inches per month were better than those equipped with rain-deflector shields. The gradual accumulation of unused attractant added to their effectiveness.

On the basis of these tests it was concluded that, for maximum performance as well as for ease of application, the toxicant should be soluble in the attractant, nonrepellent—highly toxic to flies, and capable of causing a rapid kill throughout the period between applications. Rapid knockdown proved to be essential not only to prevent excessive consumption of the methyl eugenol by the male flies when populations are heavy, but also to prevent flies that have consumed methyl eugenol from leaving the vicinity of the station and diverting other flies that might otherwise have come there.

The Canec stations were suspended with a wire bail either from vegetation or from iron rods stuck into the ground. They were durable enough to last throughout the 16-month period and withstand 217 inches of rainfall. The poisoned methyl eugenol was applied with pump-type oilers at monthly intervals to whatever portion of the square would best absorb it when water-logged, or to both sides in dry weather (Fig. 2).

EXPERIMENT ON HAMAKUA COAST.[2]—The experimental area was centered around the town of Ookala and Kaula gulch, on the wet Hamakua coast or lower northeast slope of Mauna Kea (Fig. 3) on the island of Hawaii. The treated portion of 6 square miles included all host areas in villages, gulches, or sugar-cane fields, and extended from the 200- to 300-foot high coastal pali up to the forest line at the 2100-foot elevation 2½ to 3 miles

[2] Conducted with the cooperation of the Kaiwiki Sugar Co., Ookala, Hawaii.

FIG. 3.—The Hamakua coast of Hawaii on the northeast slope of Mauna Kea, site of test of the male-annihilation method for controlling the oriental fruit fly.

inland. It was nearly 3 miles wide at sea level and 2 miles wide at the forest line. Most of the transecting gulches contained heavy stands of guava on their floors and sometimes along their rims. They were as deep as 400 feet and as wide as $\frac{1}{4}$ mile. Mangoes and other hosts were present, but guava constituted more than 95 per cent of the host mass.

Methyl eugenol bait stations were established in January 1952 and kept in continuous operation until May 1953. Initially 165 stations were established. The number was increased to 180 in February 1952, and to 215 in February 1953, in order to give better and wider protection to the area along the coastal pali. The stations were placed approximately $\frac{1}{12}$ to $\frac{1}{10}$ mile apart along 15 miles of gulch rims, along the coast, the forest line, and in the villages. The greatest number were placed on the southeast rims of the gulches or other host areas so as best to utilize the prevailing ENE trade winds for dispersal of the methyl eugenol odor to the many inaccessible areas. About 37 stations were equipped with funnel-type basins to retain flies that had been killed by the insecticide. Because of loss from winds, predators, and flies falling outside the funnels, the total fly kill was doubtless greater than estimated from the numbers caught, but these traps gave reasonably accurate indications of relative fly abundance at different locations and seasons.

Rainfall and temperature records from two elevations, 450 and 1800 feet, are given in table 2. Bright and sunny conditions prevailed at most elevations in the early morning hours, but clouds and frequent showers generally occurred above 1100 feet in the afternoons. During the 16-month period precipitation at the 450-foot elevation totaled 137.63 inches and at 1800 feet 217.89 inches.

Fruit samples were collected in 37 series, or 2 to 4 times monthly except for 1 or more short non-producing periods, usually from 2 permanent sites at each of 5 elevations in 3 general locations. The elevations selected were 300, 700, 1100, 1500, and 1900 feet plus or minus 150 feet. The sampling locations included the centrally located Kaula gulch and its laterals, representing the treated areas, and similar untreated gulches or sites 2 to 3 miles northwest or southeast of the treated area. More than 1000 samples, usually 40 to 60 fruits each, were obtained. The fruit was retained until the larvae therein had matured, when they were counted and held for emergence. Three additional series of samples were collected during the post-treatment period to determine normal infestation variability and how soon infestations might level off in the treated and untreated areas.

Monthly mean infestation indices in the treated and untreated areas during the course of the experiment are given in table 3.

Since fertile females may live 3 months, the annihilation of all males could not be expected to become fully

Table 2.—Rainfall and temperatures at two elevations near Kaula gulch, Hawaii.

Month	Precipitation (Inches)		Temperatures (° F.) Mean Maximum		Mean Minimum	
	450 Feet	1800 Feet	450 Feet	1800 Feet	450 Feet	1800 Feet
1952						
January	10.15	15.02	75	70	64	57
February	8.36	20.01	75	69	63	56
March	16.94	32.84	76	70	63	57
April	10.96	12.64	77	69	64	58
May	12.98	20.22	77	69	65	58
June	5.28	5.59	75	68	60	60
July	7.05	11.84	79	72	68	63
August	6.27	9.01	76	69	68	62
September	3.27	3.68	77	74	65	65
October	18.58	20.55	81	74	69	64
November	8.74	19.67	79	72	67	62
December	7.76	9.56	76	72	64	60
1953						
January	0.45	0.61	77	73	63	58
February	5.75	6.64	76	71	64	59
March	11.62	24.21	76	71	64	59
April	3.47	5.80	78	72	65	61
Average	8.60	13.62	77	71	65	60

effective until all old females were dead if the population should tend to remain in the treated area. Where females tend to evacuate the area in which they emerge, this procedure might be expected to become fully operative in a much shorter time.

Temperatures, rainfall, and amount of sunlight were most favorable for fly activity at the 300-foot elevation, and infestations in the untreated areas ranged from 3.0 larvae per pound of guava fruit in December 1952 to 96.6 in April 1953. Infestations in the treated area were not suppressed to any significant degree. However, the mean infestations here during the first 4 months of 1953 were only 46 per cent greater than during the same period in 1952 before the treatment became fully operative, whereas the increase in the untreated area was 142 per cent. Failure to obtain good control at this elevation is attributed to the impossibility of maintaining complete coverage of the coastal area with the methyl eugenol odors because of the strong prevailing sea-to-land trade winds.

At the 700-foot elevation, ½ to ¾ mile inland, where the bait odors were well distributed at all times regardless of wind direction, substantial control was indicated for each month except January and April 1952 and January 1953. The last sampling period came just after a period of extensive fly movement. Results were generally best during months of peak guava production. Infestations early in 1953 averaged only 39 per cent greater than those in 1952 in the treated area in comparison with an increase of 153 per cent in the untreated area. August and November post-treatment indices for the treated area were higher than those for the untreated, whereas in the same months during the treatment period they had been 93 and 67 per cent less.

At the 1100-foot elevation, about 1½ miles inland and near the center of the treated area, infestations after February 1952 ranged from 27 to 99 per cent less than in the untreated areas except in September. The low infestation in the untreated areas during this month was abnormal and may have been caused, in part at least, by the burning and harvesting of cane in fields on the windward side of the untreated areas and the use of herbicides on the newly replanted fields. When blown over the gulches the herbicides partially defoliated the guava, and burned and stunted the fruit. From January to April 1953 the infestations at this elevation increased only 20 per cent over those of 1952 in the treated area compared with 287 per cent in the untreated area.

At the 1500-foot elevation, about 2 miles inland, the infestations ranged from 33 to 100 per cent less in the

Table 3.—Control of the oriental fruit fly by elimination of males with poisoned methyl eugenol, Hamakua coast, Hawaii, 1952–1953.

Month	300 Feet			700 Feet			1100 Feet			1500 Feet			1900 Feet		
	Number of Larvae per Pound of Guavas		Difference in Treated Area Per Cent	Number of Larvae per Pound of Guavas		Difference in Treated Area Per Cent	Number of Larvae per Pound of Guavas		Difference in Treated Area Per Cent	Number of Larvae per Pound of Guavas		Difference in Treated Area Per Cent	Number of Larvae per Pound of Guavas		Difference in Treated Area Per Cent
	Untreated Area	Treated Area		Untreated Area	Treated Area		Untreated Area	Treated Area		Untreated Area	Treated Area		Untreated Area	Treated Area	
1952															
January	17.5	39.7	+127	17.1	11.2	− 35	3.5	—	—	1.1	—	—	1.2	0	−100
February	10.2	31.0	+204	7.7	0.8	− 90	2.3	5.0	+117	2.2	—	—	2.1	0.3	− 86
March	4.2	17.5	+317	7.8	1.5	− 81	1.7	0.02	− 99	2.7	0	−100	3.8	0.5	− 87
April	38.9	34.4	− 12	15.4	11.6	− 25	5.2	3.8	− 27	0.6	0.4	− 33	1.7	2.7	+ 59
May	29.5	81.8	+177	29.8	3.7	− 88	4.5	1.4	− 69	1.4	0.4	− 71	0.2	0.4	+100
August	25.0	22.0	− 12	33.5	2.2	− 93	4.4	0.5	− 89	1.6	0.0	−100	0	0	—
September	17.5	4.3	− 75	3.2	0.2	− 94	0.6	1.8	+200	2.3	0.02	− 99	0.2	0	−100
October	19.1	8.1	− 58	5.2	1.4	− 73	2.0	0.6	− 70	1.0	0.02	− 98	0.4	0	−100
November	4.9	12.3	+151	2.4	0.8	− 67	3.0	0.6	− 80	0.8	0.1	− 88	1.0	0	−100
December	3.0	4.3	+ 43	1.8	0.5	− 72	6.0	0.8	− 87	2.3	0.4	− 83	0	0	—
1953															
January	10.5	35.2	+235	5.0	5.2	+ 4	17.0	8.3	− 51	13.0	3.3	− 75	6.2	0.3	− 95
February	37.1	20.6	− 44	19.2	7.4	− 61	6.8	0.7	− 90	6.8	2.8	− 59	10.2	1.8	− 82
March	27.0	25.8	− 4	47.9	7.7	− 84	6.2	1.4	− 77	3.8	1.3	− 66	5.2	4.1	− 21
April	96.6	94.7	− 2	49.4	14.5	− 71	19.1	3.7	− 81	23.0	1.7	− 93	9.8	4.0	− 59
Mean March 1952 to April 1953	26.1	30.1	+ 15	18.3	4.7	− 74	6.4	1.9	− 70	4.9	0.9	− 82	3.0	1.2	− 60
Post treatment period															
August 1953	63.5	69.4	+ 9	22.2	53.3	+140	11.0	10.0	− 9	19.1	—	—	2.8	—	—
November	23.0	12.8	− 44	23.2	31.8	+ 37	20.6	10.6	− 49	6.6	14.9	+126	4.8	5.5	+ 15
February 1954	47.0	48.5	+ 3	19.8	7.0	− 65	4.8	1.7	− 65	2.2	0.8	− 64	0.9	4.6	+411

treated area from March 1952 to April 1953; yet they quickly became more than twice as great in November after the experiment had been terminated.

At the 1900-foot elevation 3½ times as many flies were caught in traps in January than in traps at the 300- to 700-foot level; yet early fruit infestations were very low, apparently for reasons other than treatment. The control from August through December 1952, the period of maximum fruit production, appeared to be 100 per cent, but large numbers of flies moved into the area during the last 2 months of 1952 and January 1953. After termination of the experiment, infestations at this elevation in Kaula gulch exceeded those in the untreated area.

Male fly abundance within the treated area, as indicated by trap catches during three periods of varying length, dropped to an extremely low level from April 24 to September 29 at all except the lowest elevation. During this period the average kill for stations 700 feet and above along Kaula gulch was less than 1 fly per trapday. This was only about 2 per cent of the rate during the first 20 days of the experiment (January 10 to 30) and less than 2 per cent of the rate from December 8 to January 8, a period of unusually widespread fly movement in many parts of Hawaii. Traps around the borders of the area and along the coast consistently caught more flies than those inside.

Inside the 6-square-mile treated area no living male fly was seen for several months prior to late November. During this period nearly 50 pounds of methyl eugenol was applied on the bait stations. In the untreated areas, in contrast, except at the 1900-foot elevation, many male flies were attracted to the vehicle and the operator's clothing, which were contaminated with this attractant. However, late in December at this elevation in the southeast untreated area more than 350 males came to the vehicle within 15 minutes after its arrival. No oriental fruit flies or parasites had been reared from this area during the preceding 3 months. These flies were obviously migrants and were part of the large population moving over the Hamakua coast and other parts of Hawaii at that time. Male flies were captured with methyl eugenol as high as 7600 feet on Mauna Loa in February, March, and April 1953.

FRUIT FLY PARASITE RELATIONSHIPS.—In the untreated areas the percentage of Mediterranean fruit flies, *Ceratitis capitata* (Wied.), in the total insect population ranged from 1.3 at 300 feet to 11.3 at 1100 feet and 54.0 at 1900 feet. In the treated areas the percentages were much higher at 700, 1100, and 1500 feet. This fly increased to a high level in the treated gulches from May to October 1952, when the oriental fruit fly infestations were suppressed 69 to 100 per cent. Apparently these increases resulted in part from a lessening of the competition between the two species.

Parasites constituted 22 to 58 per cent of the total emergence from pupae from the different locations in the Hamakua coast experiment. Nearly all of them were *Opius oophilus* Fullaway. Although this species parasitizes the Mediterranean fruit fly under certain conditions (Clancy 1951), all *oophilus* emergence was considered as being from the oriental fruit fly in calculations of the infestation indices. Hence the reduction estimates must be considered conservative. Undoubtedly there was some parasitization of Mediterranean fruit fly eggs when both flies laid eggs in the same site. The fact that during several monthly periods only this fly and *oophilus* were reared from fruit samples suggested either 100 per cent parasitization of the oriental fruit fly or some parasitization of the Mediterranean fruit fly.

In the untreated area the Mediterranean fruit fly and *oophilus* emerged together in the absence of the oriental fruit fly only from fruit collected at 1900 feet in September and October. In the treated area there were 10 monthly fruit collections (8 from lower elevations) from which only the Mediterranean fruit fly and *oophilus* emerged.

When the oriental fruit fly constituted less than half of the emerging flies, the percentage of parasitization based on total emergence was invariably low. Parasitization above 52 per cent on this basis was never associated with populations in which the Mediterranean fruit fly was dominant. In 14 monthly means where the total emergence was of this fly, parasitization averaged only 12 per cent. There was a tendency for *oopilus* to reappear in numbers shortly after the oriental fruit fly began to reappear.

EXPERIMENT ON KILAUEA.—Simultaneously with the experiment on the Hamakua coast another experiment was conducted in a stand of guava on the southwest slope of Kilauea on the fringe of the Kau desert. The guava trees, concentrated in an area of 7 acres, were surrounded by non-host areas consisting of pasture land to the northwest and lava flows covered principally with ohia trees to the southeast. Comparable guava areas from 1 to 3 miles southwest of the treated area were used as controls.

In this experiment 19 poisoned feeding stations as used in the experiment on the Hamakua coast were distributed in the treated area and around it for a distance of ¼ mile, and four additional stations were established ½ mile northeast and southwest. Later four more were placed between the treated areas and the crater of Kilauea for observations on migrating populations at outlying points.

During the 16-month period of the experiment a single station on the southeast rim of the Kilauea caldera at 3800 feet caught 16,000 flies, although the desert area was devoid of vegetation and there were no known hosts within 2 miles. A station on the northeast rim of the volcanic crater at the 4000-foot elevation captured 32,000 male flies. Two stations at 3300 and 3600 feet, ½ and 1 mile from the nearest fly hosts or approximately 1½ and 3 miles northeast of the treated area, caught 178,000 and 102,000 flies compared with 300,000 taken at 19 stations within or adjacent to the treated guava area. Four stations ½ mile northeast and southwest of the guavas captured 90,000 male flies. The numbers caught outside the host area are indicative of the widespread fly movement, presumably of fertile female flies as well as males, that appeared to be originating in heavily infested guava and general host areas in the Puna district 10 or more miles to the east.

The first guava crop in the Kilauea experiment was sampled at weekly intervals from January 25 to June 11,

1952. After February 10 oriental fruit fly infestations in ripe picked fruit in the treated area ranged from 3.9 to 33.6 larvae per pound with an average of 14.1. Infestations in the untreated areas ranged from 7.1 to 131.1 larvae per pound with an average of 29.3. Prior to February 10 the infestation in the treated area was 5.5 compared with 2.9 larvae per pound in the untreated area. During production of the second guava crop, from September 22 to November 26, infestations in the treated area ranged from 0 to 11.8 with an average of 6.1 larvae per pound, and in the untreated areas 4.9 to 17.0 with an average of 9.2. Mediterranean fruit fly infestations averaged 7.4 larvae per pound in the treated area but only 2.8 in the untreated.

DISCUSSION.—These and previous experiments strongly indicate that feeding stations impregnated at monthly intervals with 30 ml. of methyl eugenol containing 3 per cent of Pyrolan and distributed at the rate of 30 or more per square mile are capable of providing substantial control of the oriental fruit fly under certain conditions at very low cost. The cost in the 16-month Hamakua coast experiment, exclusive of strictly research items, was less than 35 cents per acre.

Failure to obtain complete control was due largely to immigration of fertile females into the treated areas. Successful use of the method for control purposes will probably be limited to areas where entire isolated populations can be subjected to the treatment, or to commercial fruit-growing areas where there are few oriental fruit flies produced in wild hosts. The method should be of real value for combined scouting and control usage in the event oriental fruit fly outbreaks ever occur in the continental United States.

SUMMARY.—Experiments in Hawaii have shown that infestations of the oriental fruit fly, *Dacus dorsalis* Hendel, can be reduced 60 to 100 per cent if male flies are destroyed before they can fertilize the females. In a 28-month experiment on Oahu in a 1½-mile section of a deep gulch with an abundance of wild fruit fly hosts, 45 to 55 feeding stations treated with methyl eugenol and parathion or Pyrolan attracted and killed more than 3 million male flies. Mean infestations in four successive guava crops ranged from 1.2 to 4.2 larvae per pound in the treated gulch and from 7.1 to 35 per pound in similar untreated gulches.

On the Hamakua coast a 6-square-mile area was protected for 16 months with 165 to 215 cane-fiber bait stations, each treated monthly with methyl eugenol and Pyrolan. There was no control at the 300-foot elevation along the sea where onshore trade winds prevented adequate dispersal of the attractive odors. At 700, 1100, 1500, and 1900 feet mean oriental fruit fly infestations were 74, 70, 82, and 60 per cent less, respectively, than at similar elevations in the untreated area. Control of 100 per cent was obtained during several monthly periods. Infestations at each elevation in the treated and control areas leveled off rapidly after termination of the experiment.

Suppression of the oriental fruit fly by this method accounted for marked increases in Mediterranean fruit flies, *Ceratitis capitata* (Wied.), during the summer months. Parasitization of oriental fruit fly larvae by opiine parasites—approximately 60 per cent—was not affected by the treatment. Except for the first month after their installation and a 2-month period of widespread fly movement, the bait stations kept the central portion of the treated area almost devoid of males.

A small experiment in a semi-isolated stand of guava near Kilauea volcano failed to give significant control because of migration of fertile females into the treated area. A single trap in a nearby non-host area that caught 178,000 flies during the 16-month experimental period provided graphic evidence of the normal movement of flies which is entirely independent of host availability. This experiment showed that the male-annihilation method is not suitable for small areas. It should be most effective when applied to whole or well-isolated populations, or when used in a combined scouting and control operation to combat incipient oriental fruit fly infestations on the mainland.

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Fly Control on Farms with Several Organic Thiophosphate Insecticides[1]

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Despite the revival of various nostrums and devices for fly control in recent times, there is a strong continuing interest in the use of residual sprays for controlling flies on farms. This is especially the case in those areas, such as the state of Iowa, where sprayers are generally available for applying insecticides on farms. Furthermore, in this area there are periods during the fly breeding season when more than half the flies on farms may consist of stable flies which do not seem to be attracted to baits and other devices. This study has been made primarily to evaluate the residual fly control effectiveness of several organic thiophosphate insecticides on farms. In addition, the specific toxicity of these insecticides to the house fly, *Musca domestica* L., and stable fly, *Stomoxys calcitrans* (L.), has been observed; and milk samples from dairy farms where two isomeric insecticides were used have been analyzed for residues.

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Table 1.—Organic thiophosphate insecticides used in residual fly control tests in the vicinity of Ames, Iowa, 1954.

Insecticide[a]	Application Data				
	Farm	Per Cent Active Ingredient	Formulation Used[c] (Per Cent)	Gallons Used	Date Sprayed
1. Isochlorthion	A	1.0	25 E.	40	6-30
	A	1.0	50 W.	50	7-13
2. Chlorthion (Control 65411 -1)	B	1.0	44 E.	50	7-1
	B	1.0	25 W.	60	7-13
	B	1.0+sugar[b]	44 E.	60	8-11
	C	0.5	44 E.	70	7-2
	C	2.0+sugar[b]	44 E.	60	8-4
3. Diazinon	D	1.0	25 E.	30[d]	6-30
		1.0	25 W.	30	
	D	1.0	25 W.	70	7-23
4. Penthion 80	E	0.4[c]	20 E.[e]	45	7-20
5. Piraxinon	E	0.5	25 E.	40	7-1
	F	1.0	25 W.	60	8-10

[a] Formulations of these insecticides were provided gratuitously by the following companies: 1. American Cynamid Co.; 2. Chemagro Corporation; 3 & 5. Geigy Agricultural Chemicals; and 4. S. B. Penick & Co.

[b] Sugar was included in these sprays at the rate of 4 pounds of sucrose dissolved in each 10 gallons of spray.

[c] E. and W. stand for emulsifiable concentrate and wettable powder formulations, respectively.

[d] Limited available supplies of Diazinon needed to spray this farm required use of both emulsifiable concentrate and wettable powder formulations.

[e] Malathion.

MATERIALS AND METHODS.—*Description of the farms.*—Six farms were used to evaluate the residual fly control effectiveness of the organic thiophosphate insecticides employed in these tests conducted from the latter part of June, through September 4, 1954. All farms were located in central Iowa within a 5 mile radius of Ames. Except for one instance, only the insecticides reported in this paper were used for fly control on these farms. The apparent correlation between abundant fly breeding areas and high fly populations necessitates a description of the farms which may be useful in interpreting the fly count data presented later. For convenience, all farms have been designated by a letter; brief descriptions of the farms follow. Farms A and B were dairy farms. Farm A had approximately 40 dairy cows, predominantly Holsteins, in production; other animals on this farm included bulls, calves, heifers, chickens, and hogs. Excellent sanitation prevailed on this farm throughout the fly season and fly breeding areas were relatively few. The cows at farm A were milked in the barn. Farm B had about 40 Guernseys in production; other animals on this farm included bulls, calves, and heifers. The sanitation on this farm was fair; a trench silo provided a breeding source throughout the season. Milking at farm B was done in a milking parlor.

Farm C is one used for research on swine nutrition. Several hundred pigs, including litters, were processed through this farm during the summer. All buildings used for farrowing had screens on the windows and doors. Excellent sanitation was practiced on this farm; however, the manure, which attracted large numbers of flies, was retained temporarily near the buildings in open concrete pits. The manure usually was removed from these pits every few days and spread in nearby fields; however, late instar larvae often could be found in the manure. One building on this farm was sprayed accidentally during the tests and fly counts were discontinued until the effects of this spraying had disappeared.

Farm D was operated primarily for the production of pure-bred Angus cattle; other animals on this farm included Hereford feeder cattle and hogs. At least 100 cattle were present on this farm during these fly control tests. Sanitation was fair; fly breeding places were numerous during the first half of the fly season. A trench silo on this farm did not seem to be a particularly bad breeding source for flies.

Farm E was operated for general farming and included such animals as cattle, hogs, sheep, and chickens. Sanitation was fairly good on this farm and few fly breeding areas developed during the period of these tests. At farm F considerable emphasis was placed on feeding Hereford cattle and hogs; about 75 animals were kept in and around the buildings and sheds. This farm was brought into the tests late in July. Sanitation was poor, in fact, an accumulation of manure in a barn where hogs were kept all the time provided an area that was unusually attractive to flies.

Conditions on these farms, such as failure to remove manure and fly breeding in trench silos, which contributed to high fly populations were brought to the farmers' attention. Usually some improvement in sanitation was attained but not always in time to prevent large increases in fly population.

Farms where normal fly populations could be estimated were not designated specifically, partly because of difficulty in obtaining farms where no spraying would be done throughout the fly season and partly because of limitations in time and personnel. When possible, observations were made of fly populations on other farms; however, such variables as distances between farms, migration of flies, and variations in sanitation and fly control measures on the farms made it difficult to evaluate these observations.

Estimation of fly populations.—When these tests were begun, two methods were used concurrently to estimate fly populations on the farms. In one case, the conventional large fly grill (Scudder 1947) was used and 8 to 10 readings were taken on each farm at places where the concentration of flies seemed highest. It was soon noticed that the fly grill did not provide a true estimate of the stable flies present because this species seemed to prefer to rest on vertical surfaces. The second, and preferred method of estimating fly populations consisted of selecting from 5 to 10 natural resting places where there existed high concentrations of both house and stable flies (e.g. outside and inside building walls, boards and posts, roof beams, joists, stanchions, mangers, and feed bins and troughs). Observation areas were marked off at each natural resting place; the size and shape of the areas varied. Fly abundance was the most important criterion in selecting observation areas. On this basis, it was necessary during the season to abandon a few areas and add others as the suitability of and need for certain areas changed on the farms.

An approximation of the residual effectiveness and species specificity of the insecticide formulations was obtained by observing the dying and newly dead flies on selected horizontal surfaces (e.g. inside window sills, feed

troughs, can lids, and floor space that was swept infrequently) at several of the farms. The surface under observation was cleared of flies after each inspection.

Over 99% of the flies observed during these tests consisted of house flies and stable flies. The abundance of each species was recorded in the process of estimating fly populations on the farms. A quantitative degree of resistance to insecticides by the flies in this area had not been demonstrated. All farms in this test were located within ½ mile of neighboring farms. The effect of fly migration between the test and neighboring farms was not evaluated.

Insecticides.—The organic thiophosphate insecticides used in these tests and the data pertaining to their application are summarized in table 1. Of added interest is the fact that isochlorthion (American Cyanamid 4124) and chlorthion, and Diazinon and Pirazinon are chemical isomerides.

Application equipment and procedures.—The principal application equipment included a mixing tank consisting of a 10-gallon milk can, suitable hose connections, a gear-type pump[3] operated from a tractor power take-off, and an adjustable, general purpose spray gun equipped with a No. 5 disc[4] in the nozzle. During operation, the pressure at the pump usually varied from 60 to 80 pounds per square inch; from 40 to 70 gallons of spray were used on the farms, depending upon the area to be sprayed.

The spraying procedure consisted of thoroughly spraying to run-off both actual and potential fly resting places on each farm; this generally consisted of barns, sheds, and fences. Covers were used and the spray was applied carefully to avoid contaminating feed, feed troughs, and water tanks and troughs. On farm C it was impractical to cover the many water troughs during spraying, therefore each trough was flushed clean with water after spraying. The interior of the barn on dairy farm A in which the cows were milked was always sprayed; the interior of the barn on dairy farm B in which the cows were held before and after milking was always sprayed but the interior of the milking parlor adjacent to this barn was not sprayed.

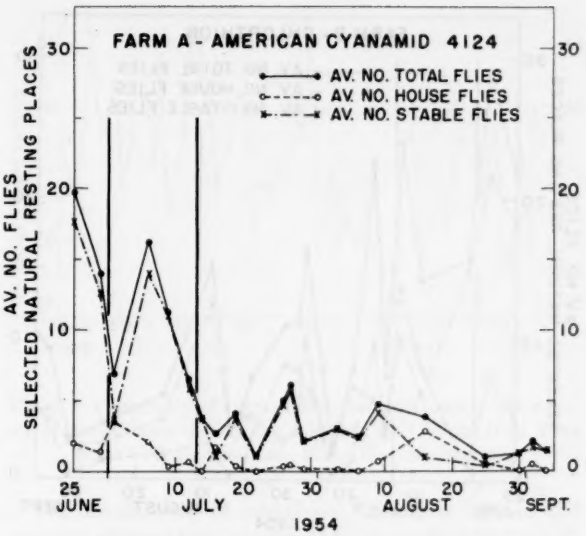

FIG. 1.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on dairy farm A, in the vicinity of Ames, Iowa during the summer, 1954. The two heavy vertical lines indiate when the farm was sprayed with isochlorthion; application data are listed in table 1.

Several procedures were employed to protect the spray applicators. Coveralls or similar clothing, respirators, goggles, and rubber gloves were worn. A shower or bath was always taken after spraying. A microadaptation (Anon. 1954) of the Michel (1949) method was used at intervals throughout the summer to determine and compare the cholinesterase activity in the blood plasma of the applicators with others who had not been exposed to organic phosphorus insecticides.

Milk Analyses.—An interest in possible insecticidal residues in milk and the availability of good analytical methods resulted in the obtaining of milk samples at several post-spraying intervals each time dairy farms A and B were sprayed with the isomeric insecticides isochlorthion and chlorthion. The application data for these insecticides and the milk sampling intervals are summarized in table 2. All milk samples were frozen, held in a deep freeze until several samples had accumulated, and then shipped via Air Express to commercial laboratories for analysis.

Table 2.—Milk analyses for insecticidal residues following applications of two isomeric organic thiophosphates for residual fly control on dairy farms near Ames, Iowa; 1954.

	Application Data				Analytical Data—Milk[d]	
Insecticide[a]	Farm	Per Cent Active Ingredients	Formulation Used[c] (Per Cent)	Date Sprayed	Date of Sampling	Post-Spraying Sampling Intervals
1. Isochlorthion	A	1.0	25 E.	6-30	6-30 7-4 7-8	5 hrs. 4 days 8 days
		1.0	50 W.	7-13	7-13 7-17 7-20 7-27	3 hrs. 4 days 7 days 14 days
2. Chlorthion	B	1.0	44 E.	7-1	7-1 7-5 7-8 7-13	3 hrs. 4 days 7 days 12 days
		1.0	25 W.	7-13	7-13 7-17 7-20 7-27	5 hrs. 4 days 7 days 14 days
		1.0 +sugar[b]	44 E.	8-11	8-11 8-15 8-18 8-25	6 hrs. 4 days 7 days 14 days

[a] Formulations of these insecticides were provided gratuitously by the American Cyanamid Co. and the Chemagro Corporation, respectively.

[b] Sugar was included in this spray at the rate of 4 pounds of sucrose dissolved in each 10 gallons of spray.

[c] E. and W. stand for emulsifiable concentrate and wettable powder formulations respectively.

[d] The isochlorthion analyses were made at the Stamford (Connecticut) Research Laboratories of the American Cyanamid Co. and the Chlorthion analyses were made in the Research and Development Department of Pittsburgh Coke & Chemical Co., Neville Island, Pittsburgh 25, Pa. The lower limits of the analytical methods are considered to be approximately 0.02 p. p. m. for isochlorthion and less than 0.1 p. p. m. for chlorthion. No residue of either insecticide was found.

[3] The spray pump was obtained from Hahn, Inc., Evansville, Ind.

[4] The No. 789, General Purpose Spray Gun used was obtained from the John Bean Div., Food Machinery & Chemical Corp., Lansing 4, Mich.

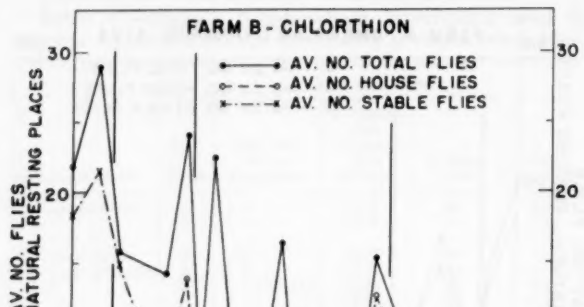

FIG. 2.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on dairy farm B, in the vicinity of Ames, Iowa during the summer, 1954. The three heavy vertical lines indicate when the farm was sprayed with chlorthion; application data are listed in table 1.

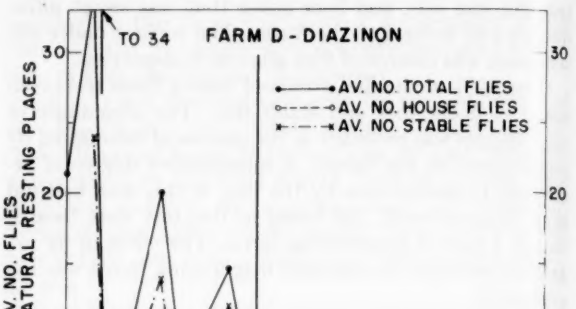

FIG. 4.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on farm D, in the vicinity of Ames, Iowa during the summer, 1954, The two heavy vertical lines indicate when the farm was sprayed with Diazinon; application data are listed in table 1.

RESULTS.—Figures 1 through 6 provide an indication of fly populations and fly control obtained with insecticides at the six farms designated A through F. The average total fly populations and average house fly and stable fly populations are shown in these figures. The average daily temperature and daily precipitation during the period of these experiments are shown in figures 7 and 8.

Unfortunately, the effectiveness of insecticidal sprayings on these farms can not be interpreted solely on the basis of the changes in fly populations shown in figures 1 through 6. Impressions obtained during actual observations at each farm during the summer must be used also to supplement the data in the graphs. In the case of dairy farm A, where isochlorthion was sprayed, stable flies were generally present in greater numbers than house flies throughout the summer. Both from observations and

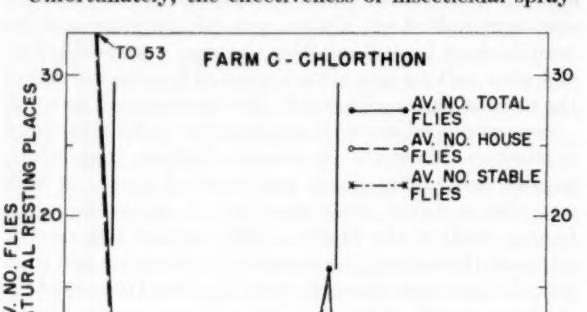

FIG. 3.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on farm C, in the vicinity of Ames, Iowa during the summer, 1954. The two heavy vertical lines indicate when the farm was sprayed with chlorthion; application data are listed in table 1.

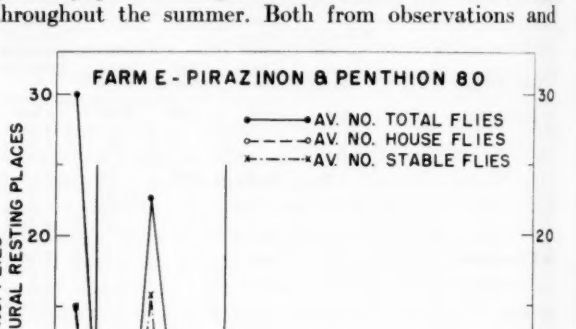

FIG. 5.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on farm E, in the vicinity of Ames, Iowa during the summer, 1954. The two heavy vertical lines indicate when the farm was sprayed with Pirazinon and Penthion-80; application data are listed in table 1.

from figure 1, it would appear that house flies were killed more readily than stable flies with this insecticide.

At dairy farm B, where chlorthion was sprayed, fly breeding was extremely high throughout the summer. Each time chlorthion was sprayed there was a temporary reduction in fly numbers. In each instance, however, it appeared that there was a greater reduction of house flies than stable flies. The effect of high fly populations on reducing the duration of effectiveness of the insecticide applications is apparent from figure 2. Although somewhat equal populations of both house flies and stable flies occurred through the summer on this farm, in late July, a prolific breeding of house flies occurred in a trench silo filled with grass silage.

Fly populations on farm C, which was sprayed also with chlorthion, consisted almost entirely of house flies throughout the summer. This is strikingly apparent in figure 3. The insecticidal applications gave good initial reductions of house fly populations.

The effect of spraying with Diazinon on fly populations on farm D is shown in figure 4. Good initial reductions of both house flies and stable flies occurred following each spray application. The existence of many fly breeding areas on this farm through the middle of July resulted in high house and stable fly populations during this period. Later in the month, most of the breeding areas were eliminated and a corresponding decrease in flies was observed (Fig. 4).

The fly populations on farm E are shown in figure 5. Two insecticides, Pirazinon and Penthion-80[5], were used on this farm. The Pirazinon treatment, which was applied first, appeared to produce an equal reduction in both house fly and stable fly populations. It is apparent that when Penthion-80 was sprayed the stable flies were at a low ebb.

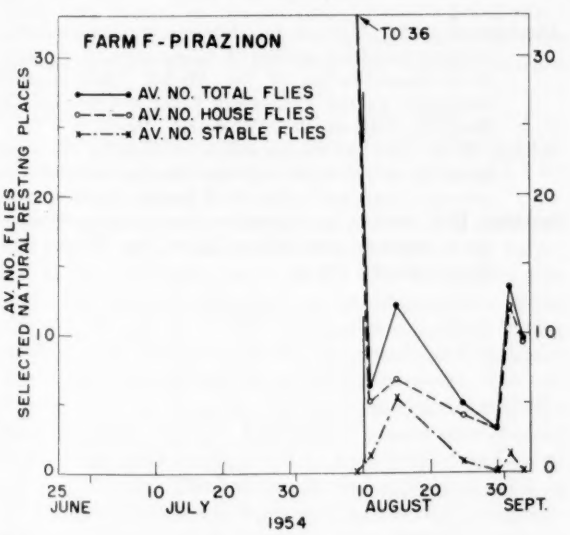

FIG. 6.—A summary of the average total number of flies and the average number of house flies and stable flies observed at a series of natural resting places on farm F, in the vicinity of Ames, Iowa during the summer, 1954. The heavy vertical line indicates when the farm was sprayed with Pirazinon; application data are listed in table 1.

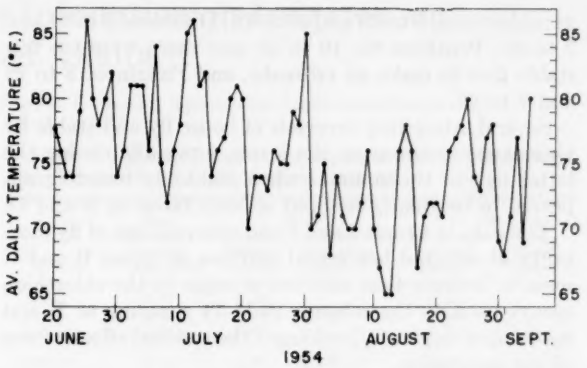

FIG. 7.—A summary of average daily temperatures in the vicinity of Ames, Iowa during the summer, 1954. Data from Iowa State College Agronomy Farm Weather Station.

The availability of additional Pirazinon late in the summer allowed this insecticide to be applied on farm F. The effect of this application on fly populations is shown in figure 6. A marked reduction in house flies was noted after spraying the Pirazinon. Although it would appear that stable flies actually increased in numbers after spraying, it may be that the evaluation of stable fly populations before spraying was difficult due to the extremely high house fly populations.

Continually changing factors affecting fly populations on the farms, of which sanitation appeared to be the most important, do not allow for simple comparisons of effectiveness between the insecticides. Nevertheless, estimates have been made of the range of residual fly control after spraying these insecticides. The following figures, based upon both over-all seasonal impressions and the data in figures 1 through 6, provide an estimated range of effective fly control in days after spraying for house flies and stable flies, respectively: isochlorthion, 13 to 28 and 9 to

[5] Malathion plus butoxy polypropylene glycol

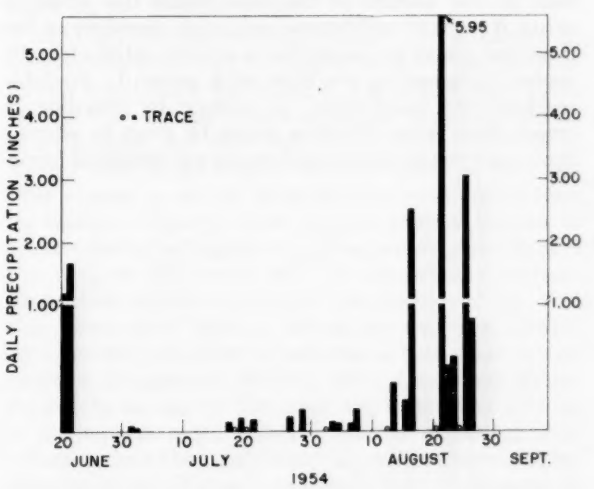

FIG. 8.—A summary of daily precipitation in the vicinity of Ames, Iowa during the summer, 1954. Data from Iowa State College Agronomy Farm Weather Station.

21; chlorthion, 3 to 28 and 10 to 28; Diazinon, 8 to 31 and 7 to 35; Penthion 80, 10 to 14 and there were too few stable flies to make an estimate; and Pirazinon, 8 to 22 and 7 to 22.

Several interesting reversals of house fly and stable fly abundance occurred on the farms, especially during the latter half of the summer when stable fly breeding appeared to be greatly reduced on such farms as B and D.

The data in figures 2 and 3 and observations of fly mortality at selected horizontal surfaces at farms B and C seem to indicate that addition of sugar to the chlorthion sprays used on these farms (8-11-54 spraying at B and 8-4-54 spraying at C) prolonged the residual effectiveness of the insecticide.

It can be seen in table 1 that five farms were sprayed over a 3-day period at the beginning of the season (i.e. farm A on 6-30, B on 7-1, C on 7-2, D on 6-30, and E on 7-1). Both authors participated in all five sprayings and observed the several protective procedures described above. Nevertheless, it was discovered that the cholinesterase activity in the authors' blood plasma had dropped to 0.42 and 0.54 delta pH units per hour on the day after the five farms were sprayed. These values can be compared to a range of 0.73 to 1.61 delta pH units per hour in 20 other determinations involving seven persons, most of whom had not been exposed to organic phosphorus insecticides. Neither of the authors could detect any unusual symptoms, especially those that have commonly been ascribed to the effects of poisoning with these insecticides. The cholinesterase values of the authors returned to normal within 1 to 2 weeks.

The analytical data for the milk samples taken at dairy farms A and B, which were sprayed with isochlorthion and chlorthion respectively, are listed in table 2. No trace of either insecticide was found in the milk samples from these farms throughout the summer.

DISCUSSION.—Two points seem worthy of mention here. First, present methods of preparing trench silos on farms often result in fly breeding areas (especially house flies) on the margins of the silos. Where this situation exists, it tends to nullify good sanitation elsewhere on the farm and it may be impossible to achieve satisfactory fly control by spraying the farm with presently available residual-type insecticides. To reduce fly breeding in trench silos, more attention might be given to altering their construction so as to reduce the wet, marginal breeding areas and to the discovery of a fly repellent and/or larvicidal chemical which could be sprayed onto the silo.

Second, there are indications that application of some of the less-acutely toxic organic phosphorus insecticides may cause a temporary, although apparently reversible, lowering of cholinesterase activity in the blood of spray applicators. If so, is there need for fuller evaluation and better understanding of this phenomenon in relation to the health of those who use these insecticides?

SUMMARY.—This study was made primarily to evaluate the residual fly control effectiveness of the following organic thiophosphate insecticides on farms located in the vicinity of Ames, Iowa: isochlorthion, chlorthion, Diazinon, Penthion-80, and Pirazinon. Emulsifiable concentrate and wettable powder formulations of most of the insecticides were used to prepare sprays which contained a 1% concentration of the active ingredient, except for three instances when two 0.5% and one 2.0% concentrations were employed.

Fly populations on the farms were estimated during the summer by observing a series of natural resting places on each farm. Nearly all of the flies observed were either house flies, *Musca domestica* L., or stable flies, *Stomoxys calcitrans* (L.). An approximation of the residual effectiveness and species specificity of the insecticide formulations was obtained also by observing the dying and newly dead flies on selected horizontal surfaces at several of the farms. Isochlorthion, chlorthion, Diazinon, Penthion-80, and Pirazinon all killed house flies effectively. Diazinon appeared to kill stable flies most effectively.

A series of post-application milk samples taken at two dairy farms sprayed with isochlorthion and chlorthion respectively, revealed no trace of either insecticide in the milk.

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Multiple Effects of Leafhopper Infestation on Irrigated and Non-irrigated Alfalfa[1]

M. C. Wilson, R. L. Davis, and G. G. Williams,[2] *Purdue University Agricultural Experiment Station*

Entomologists, agronomists, and plant pathologists have recognized that the potato leafhopper, *Empoasca fabae* Harris, seriously injures alfalfa and causes losses manifested not only in reduced yields obtained but in poorer quality. Some of the investigators who have reported losses were Graber (1941), Granovsky (1928), Jewett (1929), Johnson (1936, 1938), Ham & Tysdal (1946), Poos & Johnson (1936), Wilson (1949), Wilson & Davis (1953), and Davis & Wilson (1953).

For several years in Indiana it has been evident that damage to alfalfa from leafhopper infestation has been more severe on sandy soils having a low water-holding capacity than on heavier soils when comparable heavy infestations occurred on both soil types. In 1952 studies were initiated to compare the effect of leafhopper infestation on alfalfa that had adequate and inadequate soil moisture.

Methods.—Because of limitations in sprinkler irrigation equipment and facilities the investigators were handicapped in designing the experiment. It was necessary to use smaller plots than were desired. These smaller plots made a complete randomization of leafhopper treated plots impossible. Likewise, it was impossible to randomize the irrigated plots. Therefore, a statistical interaction study could not be made of the data.

Studies were made in a uniform alfalfa variety nursery seeded at the Purdue University Sand Field in August, 1952, without a companion crop which is the general practice on sandy soils in northern Indiana. Nine varieties randomized within replicates and replicated six times were seeded in two separate blocks of three replicates each, one block to be irrigated. Varieties were planted in 5-row plots 25 feet long with 7 inches between rows and 18 inches between plots.

Irrigation.—Three replicates in one block received overhead irrigation during the summer of 1953 and 1954. The natural rainfall and the amount of water added by irrigation are shown in table 1.

Leafhopper Control.—Each replicate in both irrigated and non-irrigated blocks was divided into two strips; one 10 feet wide and the other 15. The 10-ft. strip was sprayed to control leafhoppers using methoxychlor at the rate of 1 lb. per acre. The material was applied with a small sprayer mounted on bicycle wheels and equipped with a 10-ft. boom and using 40 lbs. pressure. The untreated strip was larger so that an ample border could be removed before harvest. Leafhopper sprays were applied to the third 1953 cutting and to both second and third cuttings in 1954. The treatment was applied as soon as the plants exhibited 2 to 3 inches of growth following harvest. No other insect treatments were applied.

Data.—Observations on plant growth determined by height measurements were made 2 weeks after the leafhopper control treatment was applied and again at the time of harvest to determine if the effect of leafhoppers on alfalfa growth differed with the availability of water to the plant. Similar observations were made in the spring of 1954 to determine if the benefits of leafhopper control would be manifested by accelerated plant recovery the following season. Likewise, observations on recovery were made in early August of 1954 following the removal of the second harvest. Yield data were obtained for all harvests. A rating of spittlebug damage to the first cutting was made in the spring of 1954.

Table 1.—Rainfall and water supplied by overhead irrigation, Purdue Sand Field, Culver, Indiana.

Month	Ave. Rainfall Inches 1900–1953	1953		1954	
		Rainfall Inches	Irrigation Inches	Rainfall Inches	Irrigation Inches
May	3.87	3.30		2.38	
June	3.53	5.07	1.0 (6/20)	5.49	
July	3.11	5.45	1.0 (7/9)	5.45	1.0 (7/2)
			1.0 (7/30)		1.0 (7/23)
August	3.27	1.47	1.5 (8/10)	2.64	1.0 (8/5)
			1.0 (8/15)		1.0 (8/11)
			1.0 (8/25)		
September	3.33	1.84		0.28	

Experiment Results.—Although a complete statistical interaction study could not be made of the data, parts of the data could be analyzed and reference to *significance* in this paper implies statistical significance.

Effect of Leafhoppers on Alfalfa Growth.—The visible effect of leafhopper infestation on alfalfa was clearly discernible in the field 1 week after a treatment to control these insects was applied. It was also apparent that the availability of water to the plant had a pronounced effect on the amount of stunting caused by the leafhoppers. Table 2 shows that on the third cutting of 1953 the average growth increase of 9 varieties 2 weeks after a leafhopper control treatment had been applied was 49% on non-irrigated plots, but only 21% or less than half as much on the irrigated plots.

Although all nine varieties studied are attractive to leafhoppers, some may be slightly more tolerant to these insects than others. For example, Davis & Wilson (1953) showed that Ranger alfalfa attracted large populations of leafhoppers, but data suggested a greater tolerance in Ranger than in most other varieties. (Data in 1953 and 1954 suggest a variety-irrigation-insecticide interaction for Ranger.) Figure 1 shows that the average increase in growth due to leafhopper control on non-irrigated Ranger was 63% or 14% more than the nine-variety average. These data further corroborate the suggestion (loc. cit.) that when other limiting factors are removed, Ranger shows greater tolerance to leafhoppers than other named varieties. In contrast, Buffalo, which Davis and Wilson showed to be one of the most non-tolerant of alfalfas to leafhoppers again shows a greater degree of non-tolerance than the nine-variety average as measured by effect on growth (Figure 1) and yield (Table 3). Even when water was removed as a limiting factor, leafhopper con-

[1] Journal paper No. 829. Accepted for publication December 28, 1954.

[2] Entomologist, alfalfa breeder, and irrigation specialist, respectively.

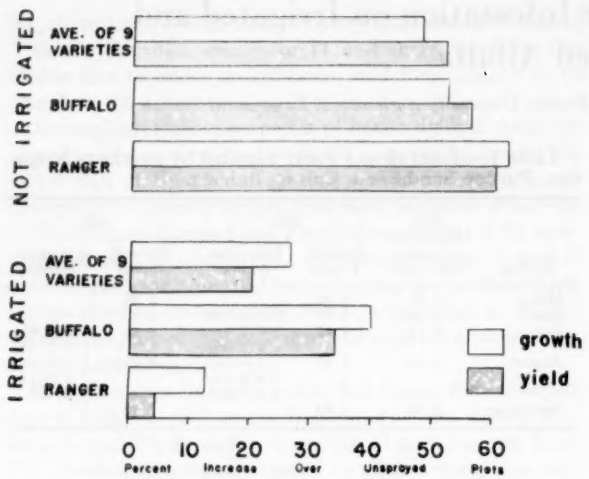

FIG. 1.—A comparison of the average increase in growth and yield in 1953 and 1954 due to leafhopper control on Ranger and Buffalo with the average of 9 alfalfa varieties.

trol increased the growth of Buffalo 39% or 13% more than average.

Effect of Leafhoppers on Alfalfa Forage Yield.—Table 3 compares the effect of leafhoppers on forage yields on irrigated and non-irrigated alfalfa for two seasons. The third cutting in 1953 shown in table 3 had less than normal rainfall while the rainfall for 1954 was greater than normal. The relationship of leafhopper damage and available water to the plants and the effect on tolerance in Ranger and Buffalo discussed in the last paragraph on the effect of leafhoppers on alfalfa growth was evident by the yields obtained.

Non-irrigated alfalfa of the varieties Ranger and Buffalo yielded ⅓ ton more per acre when leafhoppers were controlled under conditions of less than normal rainfall in 1953 with similar yields in 1954 under conditions of greater than normal rainfall.

In contrast, irrigated Ranger yielded less than 1/10 ton more per acre in 1953 and showed no increase in yield in 1954 when leafhoppers were controlled. On the other hand, irrigated Buffalo yielded ½ ton, or 62% more, per acre in 1953 and ⅓ ton, or 30% more, in 1954 when leafhoppers were controlled.

Effect of Leafhoppers on Plant Recovery After Cutting.—The rapid recovery of alfalfa following cutting was evident where leafhoppers had been controlled. Nine varieties averaged 45% more growth with a range from 35 to 65% on August 6, 1954, 1 week following the removal of the second harvest. There were no differences in recovery as a result of irrigation.

The effect of leafhopper control in 1953 on alfalfa recovery in the spring of 1954 following winter dormancy was likewise evident. There was little carryover of irrigation effects from fall to spring. On May 6, 1954, the nine varieties averaged less than 3% more growth on plots irrigated the previous season, but they averaged 18% more growth on plots previously treated to control leafhoppers. Table 4 compares forage yield and recovery as measured by increased growth on plots where leafhopper control was applied the previous season.

Effect of Leafhopper Infestation on Spittlebug Damage the Following Year.—Observations of the experimental plots in the spring of 1954 indicated that there was more spittlebug damage on the plots where leafhoppers had not been controlled the previous season. Therefore, using the 1–9 scale adopted by the National Alfalfa Improvement Conference (1-superior, 5-average, 9-poor) the plots were rated for spittlebug damage. The analysis of variance has been applied to these data and results are shown in table 5. These data show that all varieties received less spittlebug damage when leafhoppers had been controlled the previous season. None of the varieties is spittlebug tolerant. However, some appear less tolerant than others. Wilson & Davis (1953) suggested that Ranger and Buffalo were probably less tolerant to spittlebug infestations than Grimm and other selections. The data in table 5 suggest a similar relationship.

Spittlebug populations in the research plots were rela-

Table 2.—Effect of leafhoppers on plant growth on irrigated and non-irrigated alfalfa, Purdue Sand Field 1953, Culver, Ind.[a]

Variety	Leafhoppers Not Controlled		Leafhoppers Controlled				Combined Effect, Irrigation, and Leafhopper Control, Per Cent Increase
			Non-irrigated		Irrigated		
	Non-irrigated Height	Irrigated Height	Height	Per Cent Increase	Height	Per Cent Increase	
	(Inches)	(Inches)	(Inches)		(Inches)		
Nomad	7.5	11.1	11.9	59	12.4	16	65
Grimm	11.1	16.8	15.3	38	19.3	18	70
Buffalo	11.5	15.0	17.5	50	19.1	25	66
Rhizoma	9.1	14.9	13.7	50	16.2	10	78
Narragansett	9.8	15.1	16.0	62	17.0	17	69
DuPuits	11.5	15.9	17.3	50	20.9	37	78
Williamsburg	12.1	15.9	17.3	43	19.9	25	64
Kruger	11.9	16.9	16.9	42	19.7	19	66
Ranger	11.4	14.7	17.2	51	17.5	23	51
Average	10.7	15.1	15.9	49	18.0	21	67

[a] Two weeks after treatment for leafhopper control was applied.

Table 3.—Effect of leafhoppers on forage yields on irrigated and non-irrigated alfalfa, Sept. 1, 1953 (A)[a] and July 29, 1954 (B),[b] Purdue Sand Field, Culver, Indiana.

Variety	Leafhoppers Not Controlled				Leafhoppers Controlled								Combined Effect, Irrigation and Leafhopper Control Per Cent Increase	
	Non-irrigated Tons/Acre		Irrigated Tons/Acre		Non-irrigated Tons/Acre		Non-irrigated Per Cent Increase		Irrigated Tons/Acre		Irrigated Per Cent Increase			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Nomad	0.29	0.85	0.51	0.93	0.51	1.11	75	31	0.96	0.98	88	5	231	15
Grimm	.37	1.20	.88	1.53	.73	1.44	97	19	1.36	1.65	55	6	268	37
Buffalo	.47	1.02	.85	1.24	.83	1.49	77	45	1.38	1.61	62	30	194	57
Rhizoma	.39	1.57	.94	1.99	.68	1.64	74	4	1.26	2.10	34	5	223	34
Narragansett	.42	1.42	.91	1.75	.85	1.64	102	15	1.31	1.86	44	6	212	31
DuPuits	.42	1.13	1.00	1.54	.80	1.38	90	21	1.48	1.80	48	16	252	59
Williamsburg	.43	1.22	.86	1.57	.68	1.37	58	21	1.38	1.67	60	5	220	37
Kruger	.45	1.21	1.02	1.48	.84	1.59	87	28	1.26	1.70	24	15	180	37
Ranger	.45	1.16	1.02	1.50	.83	1.50	84	29	1.10	1.50	8	0	144	29
Average	.41	1.20	.89	1.50	.75	1.46	83	24	1.28	1.54	47	10	214	37

[a] Less than normal rainfall.
[b] Greater than normal rainfall.

tively low, averaging 10 nymphs per square foot May 29. Since this was an economic borderline population it is believed that the differences were more pronounced than might be evident under severe infestation. There was no evidence that leafhopper treatment had affected the adults at time of oviposition. This would not be expected since the last leafhopper treatment was applied the latter part of July and the crop was removed Sept. 1. However, removal of the crop probably reduced oviposition in the plot area during the first week of September and may account for the borderline infestation.

SUMMARY.—Data from studies designed to compare the effects of infestation by the potato leafhopper, *Empoasca fabae* Harris, on alfalfa on a droughty soil that had adequate water through overhead irrigation with non-irrigated alfalfa on the same soil showed the following results:

Within a 2-week period, leafhopper infestation reduced plant growth 28% more on alfalfa receiving less than normal rainfall than on irrigated alfalfa.

A comparison of nine varieties suggests that Ranger was relatively tolerant to leafhoppers when an adequate water supply was available. Yields from Buffalo were low when infested by leafhoppers, regardless of available water.

The rapid recovery of alfalfa following cutting was evident where leafhoppers had been controlled. Nine varieties averaged 45% more growth 2 weeks after cutting.

The effect of leafhopper control in 1953 on alfalfa recovery in the spring of 1954 following winter dormancy

Table 4.—Effect of leafhopper control on alfalfa plant recovery and yield following winter dormancy.

Variety	Recovery[a] Per Cent May 6, 1954	Tons per Acre June 6, 1954		Per Cent Increase in Yield
		Leafhoppers Controlled 1953	Leafhoppers Not Controlled 1953	
Nomad	25	1.24	.94	32
Buffalo	20	1.55	1.16	34
Williamsburg	12	1.56	1.26	24
Rhizoma	18	1.78	1.41	26
Kruger	11	1.48	1.19	24
Grimm	22	1.61	1.18	36
Narragansett	14	1.82	1.40	30
DuPuits	14	1.66	1.21	37
Ranger	10	1.48	1.17	26
Average	18	1.58	1.22	30
L.S.D. 5% level		.26	.17	
1% level		.35	.23	

[a] Per cent more growth on paired variety plots when leafhopper control was applied the previous season. Measurements showed no differences in recovery in 1954 as a result of irrigation in 1953.

Table 5.—The influence of 1953 leafhopper control on 1954 spittlebug damage on alfalfa.

Variety	1954 Spittlebug Damage Rating[a]			
	1953 Leafhoppers			
	Not Controlled	Controlled	Difference[b]	Per Cent[b]
Nomad	3.5	2.5	1.0	40
Buffalo	6.2	4.0	2.2	55
Williamsburg	5.5	3.8	1.7	45
Rhizoma	2.3	1.7	0.6	35
Kruger	6.2	3.7	2.5	68
Grimm	3.8	2.5	1.3	52
Narragansett	3.3	2.0	1.3	65
DuPuits	5.1	4.0	1.1	33
Ranger	7.5	3.8	3.7	97
L.S.D. 5% level	1.6	1.2	1.5	
1% level	2.1	1.6	2.0	

[a] Rating based on scale 1–9 (1, superior; 5, average; 9, poor)
[b] Difference in 1954 refers to increase in rating and per cent (calculated from ratings) to per cent greater spittlebug damage on alfalfa not treated for leafhoppers in 1953.

was evident by early growth response and increased yield. On May 6, 1954, nine varieties averaged 18% more growth and on June 1, the first cutting produced ⅓ ton more hay per acre on plots treated the previous season.

Spittlebug damage in 1954 was significantly less on the more vigorous plots where leafhoppers had been controlled in 1953 than on the slower recovering untreated plots.

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SCIENTIFIC NOTES

The Phytotoxicity of Malathion to Poinsettias[1]

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Malathion is an important insecticide for the control of scale insects, mealybugs, white flies and aphids. It is a comparatively safe material to handle and shows little phytotoxicity to most plants raised in the greenhouse. However, recent tests indicate that the application of malathion emulsion at concentrations necessary to control the mealybug complex may result in yellowing, curling and dropping of poinsettia leaves.

Tests were conducted at the end of 1953 and 1954 on plants which would have been marketable at Christmas time, and treatments were made just prior to, or during blooming. In 1953 three plants each were treated with emuslions at concentrations of 0.1%, 0.25% and 1%. In 1954 five plants were treated with each of the following concentrations of emulsion and wettable powders: 0.025%, 0.05%, 0.1%, 0.2%, 0.4%. Percentages are given as concentrations of actual malathion. All plants received one spraying, applied thoroughly with an electric hand sprayer.

It was found that concentrations of from 0.1 to 0.2% (about 1.3 to 2.6 pints of 50% concentrate in 100 gallons of water) were necessary to obtain good control of the mealybugs. According to the results tabulated below, some injury to the poinsettia plants was noted at these concentrations. Some curling, yellowing and dropping of leaves resulted from treatments with sprays containing 0.1% actual material, and the injury became more severe as the concentration was increased.

Treatments with wettable powder resulted in much less injury. However, the residue left by this treatment remained conspicuous and unsightly for some time. Thus since the appearance of the plant must be considered, the use of wettable powder is not desirable.

In almost every instance when the bracts had colored they were more severely affected by the spray treatments than the green leaves. These shriveled and dropped rapidly at the higher concentrations tested.

Results of these tests indicate that malathion emulsifiable concentrates cannot be safely used in the treatment of poinsettias except in the dormant period.

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	CONDITION OF LEAVES[a]											
	Wettable Powder					Emulsion						
DAYS AFTER TREATMENT	Per Cent Actual Malathion					Per Cent Actual Malathion						
	.025	.05	.1	.2	.4	.025	.05	.1	.1	.2	.25	.4	1.0
2	N	N	N	N	N	N	N			N		N	
4	N	N	N	SD	SC	N	N	N	CD	D	N	C	N
5	N	N	N	SY	SY	N	C	N	YD	Y	N	Y	N
6						Y		N			C		C
7	N	SC	SC	SY	Y	C	CY	N	YD	Y	CY	YD	CY
8	N	SC	SC	SC&Y	YD	C	YD	N	YD	CY	CY	YD	Y
9								Y			Y		D
10	N	SC		SY	SY	C	YD		YD	Y		YD	
13								YD			Y		D

[a] N—normal; C—curled; Y—yellow; D—dropped; S—slight injury.

A Larval *Ixodid* Attacking Man[1]

H. L. SWEETMAN and F. R. SHAW, *University of Massachusetts, Amherst*

In the fall of 1954 we were consulted by a local mother relative to an "insect" which she had removed from the epigastric region of her small child. She stated that the pest seemed to be attached to the skin and required considerable force to dislodge. Apparently little discomfort resulted to the child other than a local irritation.

An examination of the "insect" revealed it to be a larval tick. Unfortunately most of the mouthparts had been torn away when the tick was removed rendering identification difficult. The specimen was sent to Dr. Glen Kohls, National Microbiological Institute, Hamilton, Montana, for further identification. His reply is quoted—

"The larval tick removed from a child is clearly an *Ixodes* and in all probability it is *cookei*. I have compared it with larvae which I believe are *cookei* and can find no differences. Adults and nymphs of the latter have been reported as feeding on man, but I do not know of any reports of the larvae doing so."

Cooley & Kohls (1945) include records of the distribution and hosts of this tick. Apparently it frequently attacks domestic animals such as cats and dogs. Matheson indicates that the tick is not uncommon on man stating that he has nine such records all from central New York. He did not indicate whether these included records of larval feeding.

Inasmuch as the attacks of the larvae of *Ixodes cookei*, on man are rare or at least have not been reported in the literature, the authors felt that a note indicating the occurrence would be worth publishing.

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[1] Accepted for publication February 3, 1955.

Cantaloup Production Increased with Honey Bees[1]

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Incidental to studies of the beet leafhopper, *Circulifer tenellus* (Baker), and curly top on cantaloups in the Salt River Valley of Arizona, field observations were made that indicate that cantaloup growers can increase the yield of melons by placing honey bees, *Apis mellifera* L., near the crop. McGregor & Todd (1952) established that bees are necessary for cantaloup production and suggested placing one colony per acre near the edge of the field to insure thorough pollination.

In the spring of 1953 curly top studies were made during the early cotyledon stage of plant development in 37 fields located at random over about 10,000 acres of cantaloups within an area of 10 by 15 miles. These fields were examined twice each week for beet leafhoppers and other cantaloup insects. The beet leafhopper was the only serious pest in these fields, and practically no insecticides were applied after plants had started runners.

Three study areas were staked off in each field. These areas were located at random and each consisted of 100 feet of row. The numbers of plants were recorded and just prior to the first picking the marketable melons were counted and recorded for comparative yields.

To evaluate the benefit of honey bees in the proximity of cantaloup fields, the fields were classified into two groups—17 with no hives of bees in the visible vicinity and 20 that had hives along the border or within 1 mile of the field. The fields in the latter group had from one-fourth to one colony, averaging approximately one-half colony, per acre. No attempt was made to record the bee activity in either group, since bees appeared to be active during the blooming stage in all the fields. The data in table 1 indicate a highly significant increase in the yield of cantaloups where hives of bees are located near the crop. Greater production resulted from more plants participating in the yield, as indicated by a highly significant increase in number of melons per plant.

These data do not establish the colony-per-acre requirement for maximum production, but do confirm McGregor and Todd's findings that growers in the Salt River Valley in Arizona can increase the yield of cantaloups by placing additional honey bees near the crop.

Table 1.—Effect of honey bees on cantaloup yields in the Salt River Valley, Arizona, 1953.

GROUP	NUMBER OF FIELDS	NUMBER OF CRATES PER ACRE	NUMBER OF MELONS PER PLANT
No bees	17	161	0.67
Bees	20	242	1.06
L.S.D. (odds 99:1)	—	35	0.24

REFERENCE CITED

McGregor, S. E., and F. E. Todd. 1952. Cantaloup production with honey bees. Jour. Econ. Ent. **47**(1): 43–7.

[1] Accepted for publication January 21, 1955.

Rearing Stable Flies in the Laboratory[1]

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Several methods for rearing the stable fly, *Stomoxys calcitrans* (L.), for laboratory purposes have been reported in recent years. Doty (1937), Eagleson (1943), and Campau *et al.* (1953) successfully reared the flies in large numbers. The writers tried those procedures and developed modifications that make the rearing simpler. At the Kerrville, Texas, laboratory they have for the past 2 years reared an average of 1,500 flies per day by the method described below.

The medium is prepared by mixing 1 part by volume of standard C.S.M.A. fly medium[2] with 5 parts of wood shavings in a 7-×9-inch candy jar, and moistening with water to the point that one drop can be squeezed from a handful of the mixture. No yeast or malt is added. The jar should be approximately half full. The stable fly eggs are measured into the jar and stirred into the medium. The jar is then covered with muslin or similar cloth and placed in the rearing room, which is maintained at a constant temperature of 80° F.

The eggs hatch in 24 to 36 hours, and the larvae feed on the particles of bran, oats, and alfalfa meal in the medium. Since the larvae move about and keep the medium well mixed, it does not need to be stirred. A dry layer of shavings forms at the top, under which the larvae pupate. If desired, the dry shavings can be lifted from the pupae, which can then be removed from the

[1] Accepted for publication March 7, 1955.

[2] Purchased from Ralston-Purina Co., St. Louis, Mo.

jar and handled separately. It is usually more convenient to let the pupae remain undisturbed and release newly emerged flies directly into a holding cage. Approximately 1,000 large and vigorous flies can be reared per jar by this method.

In preparing the medium, care should be taken not to overmoisten the mixture. Should high humidity in the rearing room cause excessive moisture in the jars, the addition of a small amount of rolled oats will correct the moist situation and provide additional food for the larvae.

Fly emergence from a jar normally occurs over a period of 3 days. The newly emerged stable flies are removed from the jars each day and fed citrated beef blood as described by Eagleson (1943). The blood is fed from glass tubes 6-8 cm. long, equipped with rubber suction bulbs for taking up the blood from the container. The glass tubes are held with the open ends resting on the screen holding cage so that the flies can feed through the screen. The tubes are replenished with blood at least twice daily, usually in the morning and late afternoon.

The stable flies oviposit on a black cloth wrapped about a 1-inch ball of damp absorbent cotton. To stimulate oviposition, the cloth is wetted with a few drops of 5% ammonia solution. This ammonia-treated ball is held in a saucer or petri dish and placed in the oviposition cage. The eggs are removed the following day and measured into the rearing jar. The entire life cycle is completed in approximately 21 days.

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Notes on Parasitization of Grasshoppers by Nemestrinids[1]

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The nemestrinid flies *Trichopsidea clausa* (O.S.) and *Neorhynchocephalus sackenii* (Will.) have been reported as important parasites of grasshoppers in Montana (York & Prescott 1952).

The percentages of parasitization of the grasshopper *Metator pardalinus* (Saus.) as recorded from collections taken in southeastern Montana on August 2 and 3, 1951, are given below.

	Males	*Females*
Colstrip		
15 S. W.	56	94
13 S. W.	50	97
Broadus		
16 S. W.	46	96
6 N. W.	—	53
13 S. W.	20	50
32 S. W.	—	50
Moorhead	6	36

Three of the collections showed well over 90 per cent parasitization. The maximum reported previously was 80 per cent in 1950.

In August 1952 the area was again visited. In 2 days of travel and observations only one *Metator pardalinus* was seen. However, all other species of grasshoppers in the area were at an extremely low population level.

Dissections were also made of various range grasshoppers collected near Box Elder, in northcentral Montana. Several species were parasitized by *sackenii*, but the most heavily parasitized was *Ageneotettix deorum* (Scud.). The percentages of parasitization for this species, as determined at various times during the season, are given below.

	Males	*Females*
July 23	0	0
August 9	16	24
August 13	20	62
August 27	44	76
September 11	13	35

It is of special interest to note that with both species of nemestrinids the parasitization of female grasshoppers was much higher than that of the males.

Reference Cited

York, George T., and Hubert W. Prescott. 1952. Nemestrinid parasites of grasshoppers. Jour. Econ. Ent. **45**(1): 5–10.

[1] Accepted for publication March 21, 1955.

Corn Root Webworm Ceases to be a Pest of Tobacco in Tennessee[1]

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The corn root webworm, *Crambus caliginosellus* Clem., was for many years an important pest of tobacco seedlings in northcentral Tennessee. The larvae entered the stems of the plants at or near the soil surface and then tunneled upward and downward. The damage was confined to newly set plants and was most severe in sections where it was the practice to plant tobacco on land which had been allowed to produce weeds for several years. Large numbers of larvae became established on the roots of these weeds, especially those of the white heath aster, *Aster ericoides* L. When the land was prepared for tobacco, the weeds were destroyed during the cultural operations, and the larvae moved to the tobacco seedlings. Losses of these seedlings commonly ranged from a trace to practically 100 per cent of the initial setting. Additional damage often occurred when the larvae attacked the replants. Gilmore and Milam reported (1937) that partial control was obtained by applying 15 to 20 pounds per acre of cornmeal-paris green bait containing a small quantity of oil of mirbane (nitrobenzene). Prior to 1940 severe injury occurred each year in many tobacco plantings. Subsequent to 1940 damage decreased each year until 1944 when no economic injury was reported. No injury has been observed in Tennessee since 1943.

This marked change in the status of the corn root webworm as a pest of tobacco in northcentral Tennessee seems to be the result of a change in agricultural practices, accompanying a pronounced increase in the numbers of beef and dairy cattle during the last 15 years. This increase in the numbers of cattle required a corresponding increase in land used for pasture. Much of this pasture land was occupied by weeds which formerly harbored larvae of the corn root webworm. These weeds were consumed by the cattle. At about the same time the practice of clipping pastures and idle land was introduced. This also resulted in the destruction of many wild plants which otherwise would have functioned as hosts of the corn root webworm larvae.

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Gilmore, J. U., and Joe Milam, 1937. Improved poisoned bait for corn root webworm affecting tobacco. Jour. Econ. Ent. **30**(3): 564.

[1] Accepted for publication March 21, 1955.

Acaricide Tests on Apple in 1954[1]

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In a block of York Imperial apple trees on the J. H. Oyler farm near Arendtsville, Pa., a test was conducted during the 1954 growing season to compare the residual effectiveness of certain acaricides against the two-spotted spider mite, *Tetranychus telarius* (L.), and the schoenei mite, *T. schoenei McG.* For concentrate spraying with a mist blower, part of the orchard was divided into plots 3 rows wide by 8 to 10 trees in length. The rest of the orchard was staked into single-tree plots for dilute spraying with a gun. The single-tree plots were added to the experiment for the purpose of testing the experimental acaricide F. W. 293,[3] which was not available in large enough amounts for concentrate spraying, and also to permit the testing of Systox as shown for plots 11 and 12, table 1.

The concentrated sprays were applied at the rate of 3 gallons per tree for each application. The dilute mixtures were applied to wet the trees to the run-off point. This required approximately 12 gallons of spray per tree. Details regarding the acaricidal treatments and the mite counts are given in table 1. During the course of this experiment, captan, DDT and TDE were applied uniformly to the test trees, including the checks, in appropriate seasonal sprays.

The results of the mite counts shown in table 1 are the averages from two trees from each treatment and were made as described by Asquith & Kane (1951). In the plots sprayed with concentrates, the records were taken from two trees in the center row. From each of the dilute treatments, two of the four replicated trees were chosen for record purposes.

DISCUSSION AND CONCLUSIONS.—In considering the mite counts for July 12, it will be noted that only F. W. 293, the acaricide sprayed on plot 4, gave a high degree of control with the first application. This advantage may have been caused by the fact that plot 4 was sprayed 4 days after the other dilute-spray plots had been treated. The decrease in the mite population shown in the counts of July 26 and 27 may have been the result of some

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[2] Acknowledgment is made of the valued assistance of Guy A. Herring and William L. Coradetti.

[3] A wettable powder formulation containing 25% of α-Trichloromethyl-4,4'-dichlorobenzhydrol, supplied by Rohm & Haas Co.

Table 1.—Results of treatments against mites near Arendtsville, Penna. 1954.

Plot No.	Date Sprayed	Acaricides	Pounds per 100 Gals.	Mites per Leaf				
				July 23–24	July 12	July 26–28	Aug. 6–10	Aug. 24–25
1X[a]	7/1	15% Aramite[b]	6	53.1	19.5	0.6	2.4	6.5
	7/13	15% Aramite	6					
2X	7/1	15% Aramite Exp.[c]	4.5	125.9	54.1	0.5	0.3	7.1
	7/13	15% Aramite Exp.	6					
6X	7/1	50% Strobane[d]	4.5	69.0	39.5	5.0	48.8	114.6
	7/13	50% Strobane	4.5					
7X	7/1	50% Strobane	6	60.5	22.6	20.9	77.8	133.1
	7/13	50% Strobane	6					
8X	7/1	25% Malathion[e]	6	91.5	33.6	2.9	33.9	57.0
	7/13	25% Malathion	6					
16X	7/1	25% Malathion	6	75.8	33.6	14.2	40.5	97.9
	7/13	50% Ovotran[f]	1.5					
9X	7/1	25% Chlorobenzilate[g]	4.5	54.9	45.8	2.3	15.4	19.9
	7/13	25% Chlorobenzilate	4.5					
10X	7/1	25% Chlorobenzilate	6	76.5	44.5	1.0	10.1	10.0
	7/13	25% Chlorobenzilate	6					
13X	7/1	25% Systox[h]	1 pt.	55.2	47.8	1.5	5.1	18.4
	7/13	25% Systox	1 pt.					
4	7/6	F. W. 293	2	54.4	6.7	0.4	1.0	3.0
	7/13	F. W. 293	2					
11	7/2	25% Systox	1 pt.	64.3	52.0	2.5	17.6	54.3
12	7/2	25% Systox	½ pt.	53.0	44.6	1.4	5.0	34.5
	7/13	25% Systox	½ pt.					
3		Untreated		68.6	45.8	5.0	52.3	104.7

[a] The letter X signifies that the plot was sprayed with 3X concentrates. A 3X concentrate spray mixture contains 3 times as much pesticide per 100 gallons as a standard dilute mixture.
[b] Supplied by Naugatuck Chemical.
[c] Supplied by Naugatuck Chemical. In this formulation 15% Aramite is mixed with talc instead of clay.
[d] Supplied by Goodrich Chemical Co.
[e] Supplied by American Cyanamid Co.
[f] Supplied by Dow Chemical Co.
[g] Supplied by Geigy Agricultural Chemicals.
[h] Supplied by Chemagro Corp.

unrecognized natural factor. It may be noted that the mite population in plot 3, the untreated check, was also low at this time. The untreated trees were located in such a position that spray drift from other plots was not a factor. And, as shown in later counts, the condition of the untreated trees was still good enough to support a large population of mites. A mid-season, temporary depression of mite populations on apple trees in Adams County is encountered almost every year.

The counts of Aug. 6 and 10, which represent one tree per plot on the 6th and another on the 10th, indicate the superiority of certain treatments. In concentrate sprays, Aramite at 6 pounds in 100 gallons (plot 1X) gave excellent results. The same was true of Aramite Exp.[4] (plot 2X). As shown in table 1, the concentration of Aramite Exp. in the first spray was 4½ pounds and 6 pounds in the second spray. Cholorobenzilate at 6 pounds in 100 gallons (plot 10X) and Systox 25% at 1 pint per 100 gallons (plot 13X) also gave satisfactory control.

In the dilute-spray plots, F. W. 293 at 2 pounds in 100 gallons (plot 4) was outstanding in residual effectiveness. Also, Systox 25% at ½ pint per 100 gallons in two sprays (plot 12) gave excellent control of mites, whereas Systox 25% at 1 pint in one spray (plot 11) was not effective long enough to hold the mite population to a satisfactorily low level until the count of Aug. 6 and 10. Apples picked on Oct. 11 from plots 11, 12 and 13 showed no detectable Systox residue when analyzed by chemists of the Pittsburgh Coke and Chemical Co.

The counts of Aug. 24 and 25 indicate that under certain circumstances both of the Aramite formulations tried in this test and F. W. 293 have exceptionally long residual effectiveness against the two-spotted spider mite and the schoenei mite. In the locality where this experiment was conducted there were 1.75 inches of rain during July and 5.28 inches during the first 25 days of August. Hence, the acaricides in the test were exposed to a period of dry weather followed by a period of moderately wet weather.

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[4] A wettable powder formulation containing 15% of Aramite on talc instead of clay.

A Dairy-Barn Fogging Method for Fly Control[1]

E. H. Fisher, *University of Wisconsin, Madison*

A method for fogging quick knockdown spray in dairy barns was developed during 2 years of trials. A four-nozzle unit[2] with attached ½-gallon spray container was suspended from the ceiling, near the center of the barn. The height was adjusted to disperse the insecticide horizontally just below the lowest beams. The nozzle unit was connected to a compressor by means of hose or other suitable air-line.

This nozzle unit is engineered to disperse about 5 liquid ounces of spray per minute at a pressure of 30 p.s.i. at the nozzle. A constant pressure of about 8 p.s.i. at the nozzle is adequate for barns up to 60 feet long, 35 feet wide, and 8 to 9 feet high. Double or more this pressure is needed to fog barns about 100 feet long; two nozzle units, plus still greater compression will cover larger barns. With storage tank compressors, a pressure regulator valve may be placed in the line.

Fogging was done shortly before milking while cattle were stanchioned, and doors and windows were closed to prevent draft. Doors and windows remained closed about 2 minutes after completing insecticide dispersal. Milking operations were begun immediately thereafter.

By fogging regularly as necessary (75 to 100 times during the summer) insects were controlled in the barn and on the cattle, and cattle were afforded protection in pasture. Insects involved were house flies, horn flies, stable flies, deer flies, and horse flies, and mosquitoes. The method was applicable to enclosed holding pens for milking parlor setups, as well as for stanchion barns.

Figure 1 is of a portable unit[3] used for trials. Permanent installation of the unit in a dairy barn is more practical for the more automatic features of "pushbutton fly control."

Effective control was obtained with a deodorized kerosene spray containing 1% piperonyl butoxide plus 0.1% pyrethrins. Emulsions were used, but less satisfactorily. One ounce of spray was dispersed for each 10 linear feet of barn length, the width averaging 35 feet, and the height 8½ feet.

Paid paper
[1] Accepted for publication April 7, 1955.
[2] Insectojet 4-2 (Spraying Systems Company, Bellwood, Illinois).
[3] Courtesy Johnson Service Co. (Compressor Division), Milwaukee, Wisconsin.

Triatoma recurva Collected from Its Natural Host in Sonora, Mexico[1]

Raymond E. Ryckman, C. P. Christianson, and Dean Spencer, *School of Tropical and Preventive Medicine, Loma Linda, California*

Triatoma recurva (Stål, 1868), formerly known as *Triatoma longpipes* Barber, 1937 (Lent 1951), has not previously been collected in the field associated with its natural host (Usinger 1944, Wehrle 1939). *Triatoma lecticularius occulta* Neiva, 1911; *T. neotomae* Neiva, 1911; *T. protracta protracta* (Uhler, 1894); *T. p. peninsularis* (Usinger, 1940); *T. p. woodi* (Usinger, 1939); *T. rubida rubida* (Uhler, 1894); *T. r. uhleri* (Neiva, 1911); *T. r. sonorinaa* (Del Ponte, 1930); *T. sanguisuga indictiva* (Neiva, 1912); *T. gerstaeckeri* (Stal, 1859); and *T. recurva* are the principal species and subspecies of kissing-bugs inhabiting southwestern United States and northern Mexico. The preferred hosts for all of the *Triatoma* listed above except *T. recurva*, are wood-rats of the genus *Neotoma*. *Triatoma recurva* has never been found associated with wood-rats, whereas the lodges of *Neotoma* are practically the only habitat from which the other species of *Triatoma* may be collected. Many of the tropical species of Triatominae such as *Rhodnius prolixus* Stål, 1859; *Triatoma dimidiata* (Latreille, 1811) and *T. phyllosoma* (Burmeister, 1835) are very catholic in their feeding habits and have been found associated with several hosts under natural conditions. Usinger (1944) has pointed out that *T. recurva* (=*longpipes*) is phylogenetically allied to the *dimidiata-phyllosoma* series which inhabit tropical Mexico and Central America. If *T. recurva* formerly occupied a tropical area and has moved northward, then the difference in host specificity of *T. recurva* from that of other northern species may be explained on the basis that *T. recurva* is following feeding habits developed at a previous time and has carried this trait northward. It is of further interest to note that *T. recurva nigricollis* (Usinger 1944) extends southward along the west coast of Mexico to a tropical environment. The *Triatoma recurva* population inhabiting Arizona and northern Sonora, Mexico, may actually be considered a subspecies of the *recurva* complex which has extended its range northward into a region where more northern kissing-bugs have different feeding habits.

It is the opinion of the writers that *T. recurva* will be found on a number of vertebrate hosts in nature; however, it is believed that these hosts will, for the most part, be burrow inhabiting vertebrates associated with rock slides and boulder piles. Previous collections of *Triatoma recurva* have usually been made at lights, and in cabins; during dispersal flights these bugs fre-

[1] This investigation was made possible by a grant from the College of Medical Evangelists, Alumni Research Foundation. Accepted for publication November 19, 1954.

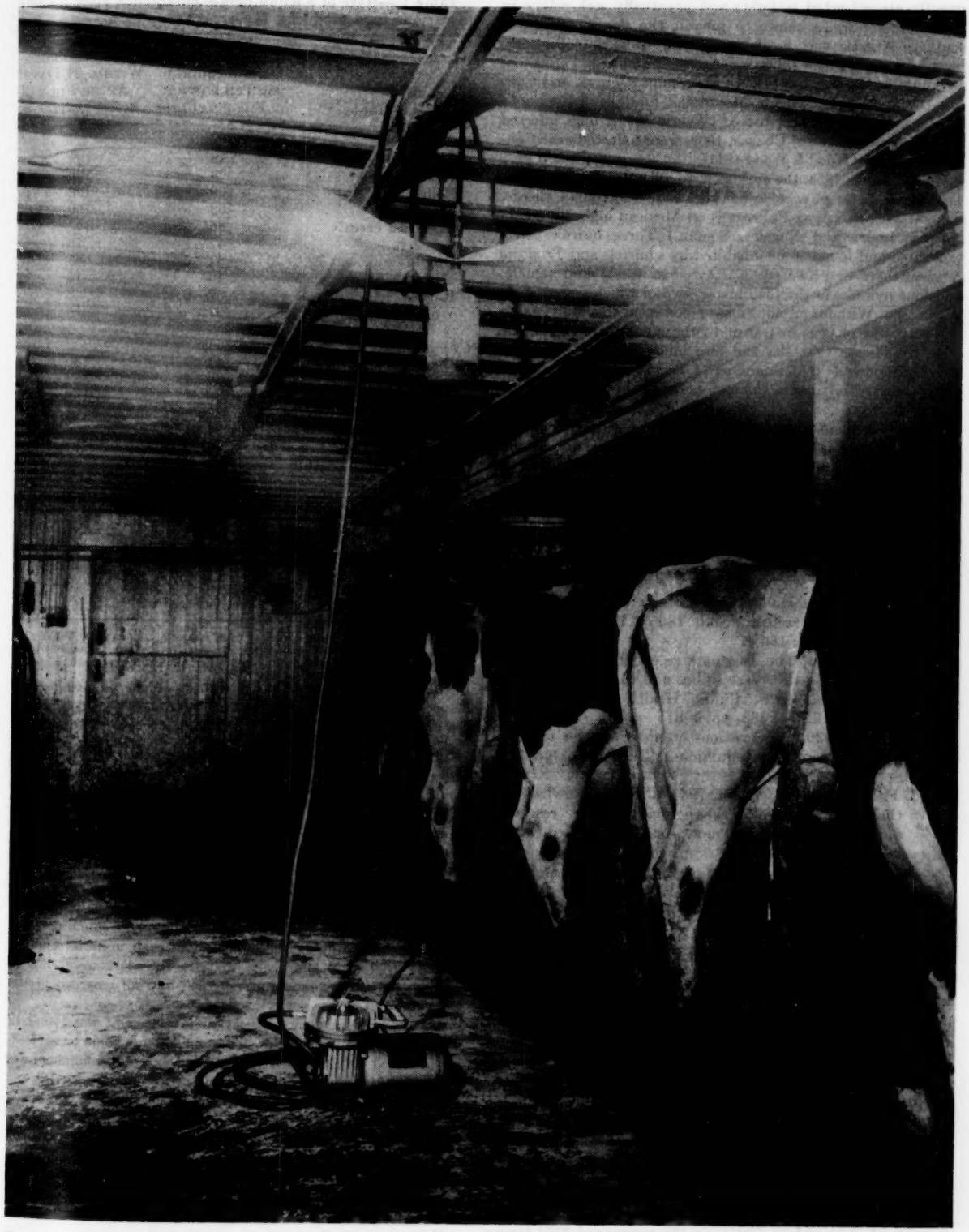

FIG. 1—A portable dairy-barn fogging unit for fly control. This ⅓ horsepower motor-driven compressor delivers 3½ cubic feet of air per minute. Insecticide is siphoned from the ½-gallon plastic spray container, and is dispersed through four nozzles. The unit can be permanently installed for greater convenience in regular use.

quently are attracted to lights and eventually seek refuge in cabins. *T. recurva* is known to inhabit the desert regions of southern Arizona and northern Sonora, Mexico; collections, have been made at the following Arizona localities: Patagonia, Reddington, Tucson, Santa Rita Mountains, Octave, and Conress (Usinger 1944); Tucson Mountains, foothills of the Santa Catalina Mountains, and Bisbee (Wehrle 1939); bugs infected with *Trypanosoma cruzi* Chagas, 1909, were collected near Congress Junction (Wood & Wood 1941).

On August 25, 1954, the authors were collecting rock squirrels, *Citellus variegatus grammurus* in a rock slide near Agua Caliente, Sonora, Mexico. (Agua Caliente is on Mexican highway no. 15 between Imuris and Nogales, Sonora.) Three burrows were excavated and found to be inhabited by squirrels and *Triatoma recurva;* there were two adult *T. recurva* (male and female) and four nymphs in the fifth instar, two of which were replete with blood. Without an additional blood meal the adult female laid a number of eggs in transit to the laboratory; this would seem to indicate that she had also laid eggs in the burrow. It is quite possible that a number of *Triatoma* nymphs escaped being collected because of the many crevices in the walls of the squirrel burrows.

Citellus variegatus grammurus has a large geographic range extending from Utah to central Sonora, Mexico; the distribution of other subspecies of the rock squirrel, *Citellus variegatus,* exceeds the present known distribution of *Triatoma recurva recurva* and *T. recurva nigricollis.* The rock squirrels mentioned above were identified by H. W. Setzer, Associate Curator Division of Mammals, U. S. National Museum.

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Food Preferences of the Khapra Beetle[1]

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Early in 1954 a survey in Arizona revealed that mills and grain elevators in the Phoenix area were heavily infested with a pest that was new to the state. The insect was identified as *Trogoderma granarium* Everts, commonly called the Khapra beetle. It has long been known in India and has become common in European countries. In the United States it has been reported from California, Arizona, and New Mexico. By the summer of 1954 infestations had been found in 25 locations in 6 counties of Arizona, according to surveys made by the United States Department of Agriculture.

Little is known about the relative preferences of this insect for various grains, seeds, cereal products, and other agricultural products of commercial importance in the United States. In an experiment at the Mesa Station in the summer of 1954 larvae were exposed to a wide range of food materials to observe the extent of survival and development into mature adults. It was particularly sought to establish whether larvae fed on intact grains can develop into adults or whether a diet of broken kernels or grain dust is necessary.

Table 1.—Rate of Khapra beetle emergence after feeding on various food products, Mesa, Arizona, 1954.

MATERIALS	DAYS REQUIRED FOR EMERGENCE OF FIRST ADULTS[a]	TOTAL EMERGED WITHIN 21 DAYS AFTER FIRST APPEARED[b]
Processed		
Corn meal	28	199
Wheat flour	28	196
Rolled oats	29	198
Bread	33	160
Breakfast cereal	36	111
Crackers	47	76
Dog biscuit	37	67
Minute rice	46	15
Raisins	57	3
Wool yarn	167[c]	—
Unprocessed		
Black-eyed peas	41	190
Sorghum	39	182
Barley	36	180
Soybeans	36	134
Peanuts (shelled)	34	133
Corn	36	67
Pinto beans	46	50
Oats	36	43
Alfalfa hay	39	25
Alfalfa seed	46	14
Peanuts (unshelled)	128	26
Cotton seed meal	46	13
Castor beans	83	3
Wheat	167[c]	—
Cotton seed	167[c]	—

[a] Refers to elapsed time in days after 50 larvae of uniform size, slightly less than half grown, were placed in ½-pint jars with food materials indicated.
[b] Based on totals of 4 replicates of 50 individuals for each material tested. (200 possible)
[c] Refers to end of experiment, at which time no adults had yet appeared.

During this experiment larvae were exposed to 25 different processed and unprocessed materials in half-pint jars. Each jar contained 25 grams of food material (or less in the few cases where the materials were bulky) to which 50 larvae, slightly less than half grown and of uniform size, were added. Four jars, containing a total of 200 larvae, were used in the evaluation of each material. All larvae were collected from grain dust on wood beams in a commercial granary in Phoenix, Arizona. All jars were covered and held at room temperature in the laboratory. The experiment extended for 167 days. Jars were examined daily until the first adult beetle appeared in each material and frequently thereafter. For each material the jars were emptied 21 days after the first adult emerged and all emerged beetles were counted.

A wide range in the rate of larval development was found. In a few foods no adult beetles emerged although some larval feeding occurred. Of the 25 materials tested, larval development was fastest on corn meal, wheat flour and rolled oats.

The least insect development was found in the jars containing raisins, whole wheat, cottonseed, wool yarn and unshelled peanuts. In fact, no adults emerged during the 167-day period in the wheat, cottonseed, or wool yarn. Larvae fed on raisins were of normal size, but they did not readily pupate. Seventy-six days after the larvae started feeding on the raisins, only three had become adults.

White minute (pre-cooked) rice lacked something vital for larval development. The larvae fed readily but did not increase

[1] Arizona Agricultural Experiment Station Technical Paper no. 349. Accepted for publication November 29, 1954.

Table 2.—Size of male and female Khapra beetles emerged from cultures of several materials, Mesa, Arizona, 1954.[a]

Material	Females		Males	
	Average Length	Range	Average Length	Range
Processed				
Corn meal	3.33	2.26–3.65	2.41	2.04–3.50
Rolled oats	3.32	2.92–3.72	2.62	2.12–3.29
Flour	3.41	2.77–3.80	2.46	2.19–3.50
Bread	3.25	2.63–3.72	2.39	2.04–3.07
Breakfast cereal	2.90	2.48–3.36	2.46	2.04–2.99
Crackers	3.03	2.56–3.65	2.42	1.90–3.21
Dog biscuit	2.98	2.41–3.58	2.15	1.75–2.92
Minute rice	2.91	2.77–3.29	2.32	2.04–2.77
Raisins[b]	—	—	—	—
Wool yarn[c]	—	—	—	—
Unprocessed seed				
Blackeyed peas	3.12	2.77–3.50	2.39	1.90–2.99
Sorghum	3.05	2.59–3.65	2.99	2.04–2.99
Barley	3.09	2.63–3.72	2.55	1.75–2.92
Soybeans	3.09	2.77–3.58	2.30	1.75–2.92
Peanuts (shelled)	3.13	2.70–3.50	2.25	2.04–2.56
Corn	3.09	2.77–3.65	2.36	1.97–2.90
Pinto beans	2.66	2.19–3.07	2.14	1.75–2.85
Oats	2.96	2.48–3.56	2.15	1.77–2.85
Alfalfa hay	3.02	2.77–3.65	2.36	1.75–2.85
Alfalfa seed	2.83	2.56–3.21	2.18	1.75–2.63
Castor beans	2.90	—[b]	2.04	—[b]
Cotton seed meal	2.81	2.43–3.07	2.45	2.04–2.19
Peanuts (unshelled)	3.08	2.77–3.65	2.25	2.04–2.56
Wheat[c]	—	—	—	—
Cotton seed[c]	—	—	—	—

[a] Measurements in millimeters.
[b] Insufficient numbers.
[c] No adults emerged.

in size. The few beetles that emerged were the smallest of any group fed on processed food (Table 2). Breakfast cereal, crackers and dog biscuits were only fair host materials. Of the unprocessed materials the most suitable foods were shelled peanuts, blackeyed peas, sorghum and barley. Soybeans were a little better than average. Larvae fed readily on castor beans but in 104 days only 3 beetles had emerged from 200 larvae.

It is obvious from this experiment that processed or milled materials were superior to their unprocessed counterparts as food for larvae of the Khapra beetle. For example, the first adult emerged from corn meal 28 days after the start of the test. In whole corn it was 36 days before the first adult had emerged. Almost three times as many adults emerged from the corn meal as from whole corn. This general trend followed in comparisons between other milled materials and the whole grains. In general, larvae fed on processed materials developed sooner, in larger percentages, and into larger adults than larvae fed on whole grain or other unaltered materials.

In storage areas it appears that the beetles prefer cracked grain or grain dust to clean, sound grain. However, after an infestation had begun in grain dust or cracked grains, it was observed that the larvae readily attacked and eventually destroyed a large part of the sound grain.

Effect on the Green Peach Aphid of Sprays of DDT against the Oriental Fruit Moth[1]

WM. L. PUTMAN, *Entomology Laboratory, Vineland Station, Ontario, Canada*

Newton & List (1946) reported that in Colorado DDT applied to peaches in September greatly reduced the numbers of the green peach aphid, *Myzus persicae* (Sulz.), the following spring. In the Niagara Peninsula of Ontario the abundance of this aphid has been reported annually since 1946 in one or more peach orchards receiving DDT sprays for the control of the oriental fruit moth, *Grapholitha molesta* (Busck). Blocks of mature Elberta peaches, usually containing 100 trees, were sprayed according to varying schedules; the only application that would affect the aphid was the last, which was made in late August, about 3 to 4 weeks before the beginning of harvest. Fifty per cent DDT wettable powder was used at 1, 1½, or 2 lbs. per 100 imperial gallons (120 U. S. gallons) with wettable sulphur as a fungicide. Similar, adjoining plots received sulphur only.

The aphid counts were incidental to those of mites and scale insects. Aphid eggs were counted on two 1-foot twigs per tree in December and aphids on 5 to 10 leaves per tree, collected from the bases of the new growth at the end of the following May or

Table 1.—Effect of DDT on the green peach aphid on peach.

Year	Dosage[a]	Date of Last Spray	Eggs per 10 Ft. of Twig, 12/1953	Aphids per 100 Leaves, 6/1954
1946	2	Aug. 26	0.5	2.0
	None		2.5	20.8
1947	2	Aug. 27	0.3	0.3
	None		9.0	4.8
1949	1.5	Aug. 24	0.7	0.5
	None		1.2	1.4
1950	1	Aug. 23	7.4	—
	None		52.1	—
	1	Aug. 23	3.1	0.3
	None		122.5	1.9
1951	1	Aug. 28	0.0	4.0
	None		3.6	10.6
	1	Aug. 30	0.8	5.9
	None		17.9	50.9
1952	1	Aug. 26	0.5	0.3
	0		3.8	4.0
1953	1	Aug. 26	17.6	—
	0		80.4	—
	1	Aug. 26	29.6	—
	0		52.1	—

[a] Pounds of 50% DDT wettable powder per 100 Imperial gallons (120 U. S. gallons).

in early June. In some years it was not possible to make spring counts. Results are given in table 1. The counts of both eggs and aphids for the plots sprayed with DDT were significantly lower at the 1 per cent level by Student's *t* test, after the logarithmic transformation.

According to Mr. J. H. H. Phillips of the Vineland Station laboratory, the fall migrants do not begin to return to peach in this locality until late September, at least 4 weeks after the last spray, and are most abundant during the first 3 weeks of October. Only the oviparous progeny of the earlier migrants produce eggs because the great majority of the oviparae are removed by leaf-fall.

Locally the green peach aphid is seldom, if ever, economically important on peach, but, in areas where it is more injurious, DDT applied for the control of the oriental fruit moth on late varieties could be expected to reduce the frequency and intensity of aphid infestations.

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[1]Contribution No. 3265, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada. Accepted for publication December 21 1954.

Rhizoglyphus solani, a Pest of Onions

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In the spring of 1953 a puzzling case of seedling injury to onions was reported from one of the muckland areas of Oswego County. The condition in many respects resembled "damping off" infection in that the affected seedlings, 1 to 3 inches in height, fell over and soon withered beyond recognition. Examination of the wilting plants indicated an injury to the roots and the presence of mites. A collection of the mites was sent to Dr. Edward W. Baker, Division of Insect Identification of the former U. S. Bureau of Entomology and Plant Quarantine for identification and subsequently reported as *Rhizoglyphus solani*.

FIG. 1.—Thin stand of onions due to early season injury by the mite, *Rhizoglyphus solani*.

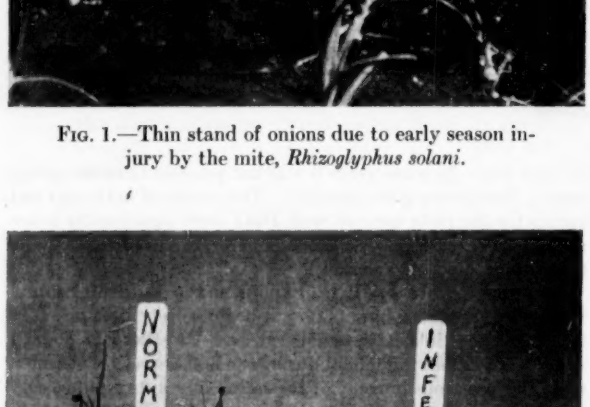

FIG. 2.—Typical seedling injury—right hand pot. Note that many of the seedlings have toppled over.

FIG. 3.—Midseason injury due to root pruning by *R. solani*. Note difference in root systems of onions from infested area (left) and uninfested area (right).

Within a few days similar cases of mite injury to seedling onions were noticed in several fields of the Orange County muckland district. In each instance the plant stand had been thinned in irregular areas of the field (Fig. 1). In two of the fields the thinned spots appeared to coincide with locations where the crates of onions had been stacked to air dry during harvest time of the previous autumn. Collections of mites from the Orange County area were likewise identified by Baker as predominately *R. solani*.

Soil from an infested area of a field was transported to the greenhouse for preliminary study. A small quantity of thiram was mixed thoroughly into the soil to prevent "damping off." The soil was divided into two lots, one of which was fumigated with methyl bromide. The two lots of soil were placed in separate series of 5-inch pots and 25 to 30 onion seeds were planted in each pot. Soon after emergence the seedlings in the unfumigated soil fell over and appeared to be injured in much the same fashion as in the field. Examination showed mites present and feeding upon the roots. When the roots were cut off at the base of the stem the plant toppled over (Fig. 2).

In the infested areas of the fields the few plants escaping serious damage grew normally until time of bulbing. Then the mites congregated at the base of roots, severing many of the roots near the bulb. Without a full complement of roots to anchor it the plant would tip over and the bulb would fail to enlarge further (Fig. 3). Yields in the infested areas were reduced sharply.

In 1954 some of the infested fields were planted again to onions and in each case the injury was evident. Growers reported that the problem was not new to them but had been considered as due to the onion maggot, *Hylemya antiqua* (Meig.).

Rhizoglyphus solani has been reported as associated with injuries to various bulbs of flowering plants along with the companion species *R. echinopus*. No earlier reports were found of *solani* as a pest of onions.

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Calendra parvula (Gyll.), a Pest of Orchard Grass[1]

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The farmers in Virginia have long regarded orchard grass, *Dactylus glomeratus*, as a valuable pasture grass and seed-producing plant. Failing stands of orchard grass have been reported for several years, the failures being attributed mostly to disease and drought. Typical symptoms were general browning of the plant, followed by death. Examination by plant pathologists failed to show diseases present in proportions that would cause the death of the plants.

In the late summer of 1953, several fields of orchard grass in Albemarle County were reported in serious condition from some unknown cause. The plants in these fields were examined and several small white legless grubs about ¼ inch long with a brown head capsule were found in the grass clumps. The stems and roots in the crown area of the plant were cut off or tunneled leaving brown "frass" as evidence of the damage by the grubs. Random sampling of orchard grass clumps in these fields revealed that 38 per cent of the stems were severely damaged.

Adult beetles were also found in the plant clumps. These insects were tentatively identified as the billbug, *Calendra parvula* (Gyll.) and specimens sent to the Division of Insect Detection and Identification, Agriculture Research Service, Washington, D. C. were identified as this species.

On June 9, 1954 a field of orchard grass was examined in Page County Virginia. This 8-acre field was completely destroyed and symptoms were the same as those seen the previous summer, only much more severe. A few adults of the billbug were found. In adjoining fields, many more adults but no larvae were collected. These fields and others in the vicinity were examined periodically during the summer of 1954. In late June, several small larvae, apparently in the first or second instar, were found in the stem of orchard grass. Three weeks later, further development of the larvae was observed, and feeding was found to have started in the lower stems and roots. The later instars of the larval stage probably cause the greatest damage to the plant. In early August, apparently full-grown larvae, pupae, and newly emerged adults were observed in abundance. One month later these insects could no longer be found in the fields.

A study of the literature reveals this insect to be widely distributed over the United States, especially in the Eastern part of the country. Early papers and reports stated that the beetle, called "the bluegrass billbug" or "the little grass billbug" was an important pest of small grain and grasses. Satterthwait (1931) listed 18 species of plants as hosts, including orchard grass. Hansen & Milliron (1942) described very severe rotting associated with infestations of *Calendra parvula* (Gyll.) on wheat, timothy, bluegrass, and crested wheat grass. The feeding injury of the weevil provided excellent avenues of entrance for fungi and bacteria.

The adult billbug is about ¼ inch long and dark brown in color. The body is elongate oval with a punctate thorax and striated elytra. This is one of the smallest species of billbugs. Apparently very little is known about the life history of this insect. It probably overwinters as an adult in woodlands and various secluded places. Forbes (1902) reported that adults, apparently still in hibernation were collected in March in woodlands. According to Webster (1892) the egg is laid in the lower part of the stem just above the roots. This was confirmed in field observations of first and second instar larvae by the writer. Smith (1913) reared several specimens of billbugs and reported the length of the incubation period of the eggs as 6 to 7 days, the larval period as 33 to 60 days, and the pupal period as 9 days. Thus, from observations in the field during the summers of 1953 and 1954, and from reports in the literature, the life history appears to be as follows: The beetles hibernate as adults probably in woodlands, emerging in the spring and laying eggs in the early summer; the eggs hatch in June and the larvae feed in clumps of grass and small grains until early August. They pupate within the clumps and emerge as adults in about 9 days. Shortly thereafter, they leave the host plant. There is probably only one generation a year. More complete studies on the biology and control of this insect are needed.

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Adaptation of Dosage-Mortality Curves to Machine Calculation[1]

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The asymmetric sigmoid dosage-mortality curve is of great importance in evaluating results of biological assays with all-or-none response. Mathematical methods of high efficiency have been developed for its study but are very time-consuming for busy experimenters. More or less unsatisfactory short-cut methods are available, but use of the full-scale calculations with reduction in working time is desirable. Adaptation to the problem of the smaller electronic calculators now in use offers some promise.

Probably the most widely used method is the log-probit, based on the normal frequency curve, developed by Bliss and summarized by Finney (1952). The logistic, instead of the normal curve, has been used by some workers and vigorously advocated by Berkson (1953 and earlier papers). The two curves give closely similar results, and both utilize information efficiently. The probit approach is somewhat preferred by the writer, as the underlying theory seems clearer than with the logistic. However, the latter seems a little more adaptable to programs for electronic calculation.

A problem will be set up with steps suitable for programming, using the logistic; a modifications needed for the probit solution will be noted. The former solution has already been put into practice, and groups of 25 to 50 curves have been done in a single run. Study is going forward on the probit solution; it seems quite feasible, but a little more lengthy and difficult. A small scale electronic data-processing machine with punched card input was used. Average time per curve is only a few minutes, after punching and wiring is done.

In the maximum likelihood solution used (Haley 1952) a provisional curve must be first derived. The situation in which the machine can help most is that in which a number of similar curves are to be calculated. Concentrations can be turned to logarithms and percentages of mortality to probits (Finney l.c.) or to "logits." If values of several sets are plotted on one diagram an equation of sufficient accuracy can quickly be derived from the graph, and used for all curves to start with. The *logit* is

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Table 1.—Example of logistic calculation, rotenone on chrysanthemum aphid Provisional equation used L = −4.5+6.6x)

LINE		CONCENTRATIONS (MG./L.)					TOTAL
1	Dose	2.6	3.8	5.1	7.7	10.2	—
2	No. treated (n)	50	48	46	49	50	—
3	Mortality	6	16	24	42	44	—
4	Proportion killed (p)	0.120	0.333	0.522	0.857	0.880	—
5	Log dose (x)	0.415	0.580	0.708	0.886	1.009	—
6	L (from equation)	−1.76	−0.67	+0.17	+1.35	+2.16	—
7	P (from L)	.147	.334	.543	.794	.897	—
8	Q (=1−P)	.853	.666	.457	.206	.103	—
9	PQ	.125	.222	.248	.164	.092	—
10	Wt. (W) as n PQ	6.250	10.656	11.408	8.036	4.600	40.950
11	$p-P$	−.027	−.001	−.021	+.063	−.017	—
12	$(p-P)/PQ$ (adjustment)	−.216	−.005	−.085	+.384	−.185	—
13	$L+(p-P)/PQ$ (working 1)	−1.98	−0.67	+0.09	+1.63	+1.98	—
14	W1	−12.375	−7.140	+1.027	+13.099	+9.108	+3.719
15	WX	2.594	6.180	8.077	7.120	4.641	28.612
16	WXl	−5.1356	−4.1412	+0.7271	+11.6057	+9.1900	+12.2460
17	WX^2	(Summed on machine)					21.3705

Mean l or $\bar{l}$ is +3.719/40.950 or +0.091
Mean x is 28.612/40.950 or 0.699
Sum of products of deviations, +12.2460−(3.719×0.699) or +9.6464
Sum of squares of deviations in x, 21.3705−(0.699×28.612) or 1.3707
Regression coefficient, b =9.6464/1.3707 or 7.04
Intercept, a, is 0.091−(7.04×0.699) or −4.83
The new equation is L = −4.83+7.04×
The log of the LD-50 is 4.83/7.04 or 0.686 ; the LD-50, 4.85

the natural logarithm of p/q, where p is proportion of mortality and q is its complement.

The only values required for the punched cards are the concentrations, the number of subjects treated and the number succumbing, and this preliminary equation. The data shown by Finney (l.c.) in his illustrative problem (Table 6) are utilized. The probit solution of this same problem is shown by Finney in detail.

Table 1 gives estimates most often wanted. Other calculations can be made much as with the probit, since the same conditions, of linear regression and weighting by reciprocal of expected variance, are found. As stated, all these calculations are done by the machine in a few minutes. If the solution is far from the preliminary graphic estimate, another cycle may be run, starting with the equation just completed; and further cycles may be carried out till stability is reached. In the first cycle, we may have several sets of data with one provisional equation; in later cycles, each set will have its own equation. Additional cycles will not add much to time with the machine.

The observed proportion, p, is calculated from lines 2 and 3; q is 1−p. Then p/q is calculated, its log is taken, and multiplied by 2.3 to get the natural log. The provisional equation is estimated graphically from a plot of X against these natural logs. The equation yields estimates of L, the expected logit. This is multiplied by .4343 to secure the common log; the antilog is P/Q, or $P/(1-P)$, from which the expected values P and Q may be derived by simple algebra. Other calculations proceed as shown.

The problems of programming can mostly be seen from the table. The most difficult is that of deriving the antilog of L, which is done by using an infinite series. The log of concentrations (X) is also estimated from a series. Other operations are simpler. The use of prepared tables, helpful in desk calculation, must be dispensed with in electronic calculation for greatest efficiency. The logit equation looks quite different from the probit, as the regression coefficient is higher (about 1.7-fold) and the a value is always a large negative. The logit as used here takes a zero value at 50%, and negative values at lower percentages, while the probit has its arbitrary addition to make all values positive. Final results (LD-50, variance, etc.) are very similar.

The probit calculation is a little more involved, but will follow the same path as that of table 1. The first 5 columns are exactly the same. Probits for plotting to get the provisional equation ($Y=a+bX$) are taken from Finney's tables. Getting P expected, from Y calculated from the equation, amounts to integrating the normal frequency curve. Peters and Van Voorhis (1940, pp. 301–302) give workable arithmetic formulae for this, and for calculating the normal ordinate, Z. The weight is NZ^2/PQ; the working probit, y is $Y+(p-P)/Z$. From there calculations proceed as in table 1.

The formula for P is:

$$P-0.5=1/\sqrt{\pi}\left[t/\sqrt{2}-\frac{1}{3(1!)}(t/\sqrt{2})^3+\frac{1}{5(2!)}(t/\sqrt{2})^5-\cdots\text{etc.}\right],$$

where t is $Y-5$. Eight terms or fewer are usually enough.

Ln (Z) is calculated as $-0.92-(t^2/2)$, and Z as the antilogarithm.

It is believed that these methods may in some cases add to the facility of use of dosage mortality curves in research.

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Diazinon and Pirazinon in Fly Control[1]

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Diazinon was first tested for fly control in New Jersey dairy barns in 1952. This work was reported by Hansens & Bartley (1953). These tests showed that Diazinon gave remarkable control of flies that had become resistant to chlorinated hydrocarbon sprays (Hansens 1953). In laboratory tests, Pirazinon showed great promise for the control of house flies. Accordingly tests were set up in Monmouth and Middlesex Counties, where work had been done previously, and also in Salem and Sussex Counties. A number of formulations were included in these tests to determine their relative value and the results reported here were done cooperatively by workers in the Entomology Department of Rutgers University and Geigy Agricultural Chemicals, Division of Geigy Chemical Corporation.

Diazinon is a colorless liquid which boils at 83–84°C. under 0.002 mm. mercury. It is soluble up to 0.004 per cent in water and readily soluble in most organic solvents.

Pirazinon, the technical product (about 90 per cent pure), is pale to dark brown. It is relatively insoluble in water and dissolves readily in petroleum solvents as well as alcohol, xylene, and acetone.

Diazinon was used as a wettable powder at 1 per cent and 0.5 per cent concentration, and at the 0.5 per cent concentration with 20 pounds of sugar added to each 100 gallons of spray. In addition 0.5 per cent Diazinon was used in combination with 0.5 per cent methoxychlor as wettable powders. Diazinon wettable powder was compared with Diazinon emulsifiable solution at the 0.5 per cent concentration in combination with sugar. Diazinon emulsifiable solution at the 0.5 per cent concentration was also tested with 0.5 per cent methoxychlor, 0.5 per cent Kenflex "A"[2], and 0.5 per cent Aroclor 5460[3].

Pirazinon wettable powder was tested at 1 per cent and 0.5 per cent concentrations without sugar and at the 0.5 per cent concentration with sugar added.

METHOD OF APPLICATION.—In spraying barns, all walls, ceilings, stanchions, and other exposed surfaces were covered to the point of run-off. Spray was applied from a 50-gallon Bean power sprayer, using a single nozzle orchard spray gun and 150 to 200 pounds pressure. Feed troughs, watering cups, and feed in the barn were covered with canvas before spraying. In addition to the barn, adjacent sheds, manure handling equipment, and doorways were sprayed. In practice, each gallon of spray covered 200 to 300 square feet of wall surface, depending on materials used in barn construction. Cinder block and certain types of porous wall board construction required larger amounts of spray than metal and painted surfaces. Barns were resprayed as necessary, i.e., as soon as possible after flies were recorded as numerous to abundant.

METHOD OF EVALUATING RESULTS.—Four types of counts were made in each barn. Counts were made three times each week, usually Monday, Wednesday, and Friday. The types of counts were as follows:

1. Fly index—an observation of the total flies of all kinds in the barn and the approximate index assigned of the following 5 categories: scarce, few, fairly numerous, numerous, and abundant.

2. Stanchion count—flies resting on two groups of three stanchions were counted and recorded.

3. Grid count—Flies were recorded on 6 Scudder grids, 18 inches square, placed in the barn where flies were most numerous.

4. Net count—In Monmouth and Middlesex Counties, 10 sweeps of an insect net were made twice each week, and flies were counted.

In evaluating control, it was found that a combined count of 60 flies on 6 stanchions and 6 grids indicated that control had failed and respraying was necessary. The fly index and net counts were also taken into consideration in making a decision on effectiveness of the insecticides.

Table 1.—Fly control from residual sprays.

INSECTICIDE	AMOUNT PER 100 GALS.	BARN	TREATED	DAYS CONTROL
Diazinon, 25%, W. P.	32 lbs.	9	May 31	19[a]
		9	July 2	59
		13	May 29	116
	16 lbs.	8	May 31	23
		8	July 2	55
		15	May 29	116
		27	June 10	32
		27	July 23	48
	16+20 lbs. sugar	2	May 31	19[a]
		2	July 1	54
		14	May 29	116
Diazinon, 25%, W. P.+ Methoxychlor, 50%, W. P.	16 lbs. 8 lbs.	4	June 3	27[a]
		4	July 1	49
		26	June 15	43
		26	Aug. 11	51
Diazinon, 25%, Emul.	2 gals.+20 lbs. sugar	5	June 3	27[a]
		5	July 1	50
		22	June 2	42
		22	Aug. 10	43[b]
Diazinon, 25%, + Methoxychlor, 25%, Emul.	2 gals.	3	June 3	43
		25	June 15	43
		25	Aug. 15	51[b]
Diazinon, 25%+ Arochlor 5460, 25%, Emul.	2 gals.	18	Aug. 19	34[b]
Diazinon 25%+ Kenflex "A," 25%, Emul.	2 gals.	34	Aug. 25	15[b]
Pirazinon, 25%, W. P.	32 lbs.	12	May 29	116
		29	June 10	48
		29	Aug. 25	15[b]
	16 lbs.	11	June 3	39
		11	Aug. 19	34[b]
		28	June 10	42
		28	Aug. 25	15[b]
	16+20 lbs. sugar	23	June 2	19[a]
		24	June 2	77
	16+10 lbs. sugar	23	July 2	63

[a] Barn re-sprayed because of *Fannia* spp; house flies not present.
[b] Still giving control at end of season.

SEASONAL FLY POPULATIONS.—Early in the season *Fannia* appeared in large numbers in nearly all barns under observation in Monmouth and Middlesex Counties and in many of the barns in Salem county. *Fannia* remained the dominant fly until the end of July when it disappeared rapidly because of an extended period of extremely hot, dry weather. The hot, dry weather reduced the number of areas favorable for fly breeding.

RESULTS.—The treatments, dosages, and dates of application, along with the number of days of fly control for each application, are given in table 1. It is evident that there was great variation in the effectiveness of the various formulations. This variation can be explained by the complication of the *Fannia* problem and by dry weather. The prolonged dry spell in midsummer made conditions for fly breeding unfavorable. Those figures with a superscript *a* in the last column of the table were locations where failure of the spray was caused by the large populations of *Fannia,* and it was necessary to respray the barn to reduce their numbers. The constant hovering of *Fannia* makes this species less susceptible to control by residual sprays.

Diazinon was tested in eight formulations, and it was effective

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology, New Brunswick. Accepted for publication January 4, 1955.
[2] A condensation product of dimethyl naphthalene condensed with formaldehyde manufactured by Kenrich Corporation, Maspeth, New York.
[3] A chlorinated terphenyl manufactured by the Monsanto Chemical Company, St. Louis, Missouri.

for an average of from 40 to 50 days in all of them. In three barns, Diazinon formulations sprayed on May 29 gave excellent control of flies for the entire season. The long period of control was influenced by the weather conditions, i.e., the long period of dry weather which made conditions unfavorable for fly breeding. There was no appreciable difference in fly control between the emulsifiable concentrate and wettable powder formulations. Under the conditions of these tests, there was no difference in fly control between the 1 per cent Diazinon and 0.5 per cent Diazinon sprays. The addition of sugar or methoxychlor to Diazinon sprays did not enhance the control. Two resinous compounds added to Diazinon sprays and applied late in the season gave control of flies to the end of the season. Their relative value could not be determined.

Pirazinon gave results nearly equal to those given by Diazinon.

SUMMARY.—Tests of various formulations of Diazinon and Pirazinon for fly control were made in 21 barns in New Jersey in 1954. Eight formulations of Diazinon gave fly control for an average of 40 to 50 days. In three barns, a single treatment gave control for the entire season. Results with Pirazinon were equal to those obtained with Diazinon.

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The Effects of Relative Humidity on the Lone Star Tick[1,2]

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Previous authors have commented on the necessity for maintaining a high relative humidity when rearing ticks (Hooker *et al.* 1912). In laboratory studies (Sacktor *et al.* 1948) it was shown that about 85 per cent relative humidity was near optimum for development. Nowhere in the literature are there data to show how low the humidity must be to prevent survival. This study, admittedly preliminary, arose from the observation that eggs sometimes failed to hatch and larvae died apparently from lack of moisture. Furthermore, it was noted that most of the ticks in the field are found in brushy areas and practically none in open pasture. The practical question posed was what factor caused the ticks to be restricted to such areas.

LABORATORY METHODS.—Dessicator jars were used as humidity chambers. Saturated salts (Buxton 1931) were used in the initial tests but potassium hydroxide (Peterson 1953) was used later because it was easier to obtain the relative humidity desired. A Serdex hygrometer was used to check the humidity.

Engorged females were collected from cattle and placed in glass tubes for oviposition. The ends of the tube were screened to retain the hatching larvae but free circulation of air was permitted. Tubes were placed in the humidity chambers. Larvae were taken from a recently hatched egg mass and treated in a similar manner. The humidity chambers were kept in a constant temperature cabinet at or near optimum temperature (Sacktor *et al.* 1948).

LABORATORY RESULTS.—Females exposed to 7, 25, and 47 per cent humidity either did not oviposit or their eggs failed to hatch. Normal oviposition and hatching occurred at 73 and 91 per cent. Data are presented in table 1.

Further studies indicate that the dividing line for hatching of the eggs more closely approaches the 73 per cent than the 47 per cent level. Females exposed to 69 per cent laid eggs but there was no hatch. At all humidities of 73 per cent or above, oviposition occurred and hatching proceeded normally. Data are presented in table 2. An interesting side light is that high humidity tends to shorten the preoviposition period and the longevity of the female and to increase the incubation period.

Table 1.—Effect of relative humidity on oviposition and incubation of the lone star tick.

RELATIVE HUMIDITY, PER CENT	♀	OVIPOSITION—DAYS		INCUBATION PERIOD, DAYS
		Began	Complete	
7	A	—	19	No hatch
	B	None	None	—
25	A	—	19	No hatch
	B	None	None	—
47	A	None	None	—
	B	6	14	No hatch
73		4	19	27
91	A	4	19	24
	B	6	11	35

Table 2.—Effect of relative humidity of the preoviposition, longevity of the female and incubation of the lone star tick.

RELATIVE HUMIDITY, PER CENT	No.	AVERAGE NUMBER DAYS		
		Preoviposition	Longevity	Incubation
69	6	10	24.3	No hatch
77	18	—	—	23.6
85	49	7.7	24.4	26.4
91	13	5	19.8	28.5

Exposure of unfed larvae to humidities of 51 and 59 per cent resulted in complete mortality in 2 days. At 65 per cent most of the larvae died within 2 days but some survived for the third day. Similar results were obtained at 69 per cent. Forty larvae were used at each humidity.

Similar tests run with engorged larvae showed that at humidities of 69 per cent and below molting did not occur. Most of them were completely dessicated and apparently dead within 11 days.

FIELD STUDIES.—An attempt was made to determine the correlation of humidity under various conditions of cover in the fields to the results obtained in the laboratory. The instruments used were a hand aspirated psychrometer and a portable hygrothermograph. The readings obtained with the hygrothermograph are at best only approximations and do not measure the humidity which may prevail between the leaf mold and the soil surface. The sensitive element was about 1½ inches from the surface on which the instrument rested. Measurements designated as the humidity at the ground level were determined by holding the psychrometer as close to the ground as possible while taking the reading. All data were taken from July 14 to August 21, when eggs and larvae would normally be in abundance in the field.

Readings taken from eight collecting stations between 2:30 and 4:00 P.M. ranged from 32 to 43 per cent. Twenty-four-hour records by hygrothermograph in brush and in open pasture

[1] *Amblyomma americanum* (L.)

[2] Research paper No. 1138, Journal Series, University of Arkansas. Published with the permission of the Director of the Arkansas Agricultural Experiment Station. Accepted for publication Jan. 3, 1955.

ranged from an average hourly reading of 55 to 32 per cent, respectively. The humidity in the brush averaged slightly higher than in open pasture. More significantly, the humidity in the brush went above and stayed above 60 per cent for a longer time than it did in open pasture. On 2 of the 3 days recorded, the humidity never reached 60 per cent in the open pasture.

Reference data taken from an open pine grove, a brushy locust grove, and an open pasture illustrate some of the differences which may occur (Table 3). There is a tendency for the humidity

Table 3.—Per cent relative humidity at the ground under various cover.

Date	Time	Humidity—Per Cent		
		Pine Grove	Locust Grove	Open Pasture
7-14	3 to 4 A.M.	35	63	33
7-15	6 to 7 A.M.	56	60	59
	4 to 5 P.M.	33	31	28
7-16	6 to 7 A.M.	65	69	58
7-23[a]	3 to 4 A.M.	92	92	73
7-24[b]	5 to 6 A.M.	80	82	83
8-21	5 to 6 A.M.	81	81	84
	1 to 2 P.M.	44	53	49

[a] Cloudy, light sprinkle of rain.
[b] Cloudy.

under open conditions to be slightly lower than under conditions of dense cover. These data further show that under the seasonal conditions prevailing, the humidity is sometimes too low to permit hatching or larval survival even under conditions of cover suitable for ticks.

SUMMARY.—Periods of prolonged drouth have occurred in Arkansas for the past three seasons. Rainfall has been scanty and occurred only as local showers. On the basis of the data presented there is little doubt that lack of moisture has contributed to the reduction of the lone star tick. High survival has probably resulted in areas where local showers fell at critical times.

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Insects Affecting Alfalfa Seed Production[1]

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A preliminary test was conducted in the Panhandle area of Texas near Wellington during the summer of 1954 to determine the effects of certain insects on alfalfa seed production. Insects involved in this study were thrips, *Frankliniella occidentalis* (Perg); plant bugs, *Lygus lineolaris* (P. de B.); and leafhoppers, *Aceratagallia uhleri* (Van D.) and *Scaphytopius acutus* (Say). Toxaphene was used because it has been applied by farmers in this area for the control of insects attacking alfalfa. The primary object of the test was to compare the effects of various numbers of applications of the insecticide. It is believed that insect populations are too low during some seasons to warrant chemical control.

The experiment consisted of one, two, three and four applications of toxaphene treatments at the rate of approximately 2 pounds of active ingredient per acre. The size of each plot was 1/10 acre and each treatment was replicated four times. Spray emulsions were applied with a compressed air sprayer equipped with a regulator valve, pressure gauge and a 5-foot boom. Nozzles were spaced at intervals of 20 inches along the boom, the spray covered a swath of approximately 6 feet and delivered about 5 gallons of spray per acre. Sprays were applied in the evening or in the early morning, at which time few bees were visiting the alfalfa and when wind velocities were low. Intervals of spray applications ranged from 7 to 11 days. First treatment was made on July 2 at which time the alfalfa was in the pre-bloom stage. One cutting of alfalfa had been harvested immediately prior to growing a crop for seed production. Seed yields were taken from a 14-foot swath of each plot with a self-propelled combine harvester.

Lygus, leafhopper and bee populations were sampled by making 100 sweeps in each plot with a 16-inch insect sweep net. Thrips populations were obtained on the basis of the number found on 36 alfalfa blossoms per plot. The fresh blossoms were clipped and allowed to fall into a quart ice cream container, the inside of which had been treated with 50% dieldrin wettable powder. The samples were kept in the containers for 3 days and then poured on to a piece of white cardboard 36 inches square. The dried alfalfa blossoms were shaken above the cardboard,

[1] Accepted for publication January 5, 1955.
[2] Thanks are due J. W. Thomas, County Agent, Collingsworth County, Texas, for his assistance in conducting this test.

Table 1.—Effect of toxaphene applications to alfalfa on insect populations and seed yields. Wellington, Texas. 1954.

Number of Treatments[a]	Dosage[b]	Lygus		Leafhoppers		Thrips		Pollinators[d]	Yield	
		Population[c]	Per Cent Control	Population[c]	Per Cent Control	Population[c]	Per Cent Control		Pounds /Acre	Per Cent Gain
1	2.2	10.3	58	29.0	20	106.8	32	2.0	735	2.7
2	2.0	5.3	79	24.5	31	70.6	55	1.6	778	8.7
3	2.0	2.4	90	19.8	44	70.6	55	3.5	782	9.2
4	2.1	2.0	92	19.6	45	51.5	67	3.2	879	22.8
None		24.8		35.6		157.6		2.8	716	

[a] All treatments replicated four times. Applications made July 2, 13, 23, 30.
[b] Pounds active ingredient per acre.
[c] Per 36 alfalfa blossoms.
[d] Per 100 sweeps of 16-inch collecting net.

disposed of and the thrips were counted. Insect population counts were taken at 3 to 6 day intervals.

The alfalfa seed production in the Wellington area during 1954 was greater than the average yield, table 1. This experiment was conducted on land considered more productive than the average soil in this area, as the farm on which it was located was in a low area and considered sub-irrigated. A similar experiment was conducted on land less productive but no significant increase in yield of alfalfa seed was obtained by controlling insects.

Insect populations were low during the entire experiment. The untreated plots averaged 24.8 lygus and 35.6 leafhoppers per 100 sweeps, and 157.6 thrips per 36 alfalfa blooms. Insect control in general was unsatisfactory although populations of lygus bugs were reduced greatly. The greatest gain in alfalfa seed yield was obtained by the use of four applications of toxaphene at 2.1 pounds per acre. The areas thus treated had increased yields by 22.8 per cent while those plots receiving only one application of toxaphene showed an average gain of only 2.7 per cent. It is believed that had lygus populations been appreciably larger, yield differences would have been greater. The tests showed that the insecticide had very little effect on populations of pollinating insects.

Outbreak of the Filbertworm on Walnuts in Northern California[1]

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In portions of the Sacramento Valley the filbertworm[2] *Melissopus latiferreanus* (Wlsm.) was extremely destructive during the 1954 season. The infestation was the most serious encountered since the walnut insect investigations were begun in 1942. In 1943 destructive infestations of the harvested crop were reported from several orchards in the Live Oak-Gridley area of the Sacramento Valley. At that time it was believed that the damage was inflicted by the codling moth. As a result, a series of experimental plots were established in 1944 to determine whether the treatments that were effective in controlling the codling moth at Linden, San Joaquin County, would also prove effective against the pest in the Sacramento Valley. The investigation showed that the codling moth infestation in the orchard where the plots were located was light, but that just before harvest many of the nuts suddenly became infested. The caterpillars responsible for this late invasion were determined to be those of the filbertworm. The infestation in the harvested crop approached 20 per cent or more. Further, the investigation showed that treatments directed against the codling moth were not effective against the filbertworm.

Subsequent investigations by Bacon *et al.* (1948) showed that the filbert worm was unable to penetrate the sound husks of walnuts and that infestation does not occur in merchantable walnuts until the husks begin to crack in late August and September. They found that the larvae penetrate these breaks and enter the nut proper through the stem end. The seriousness of the infestation increased as the season advanced. Bacon and his co-workers also found that the larvae of the filbertworm were unable to develop on cured nut meats. These workers directed sprays against the pest but none of the treatments resulted in adequate control. Because of the ineffectiveness of chemical measures the pest can best be checked by harvesting and drying the crop at the earliest possible date.

Filbertworm adults are found in walnut orchards during most of the growing season, despite the fact that the caterpillars are unable to enter the nuts until the husks begin to crack. The principal source of moths that infest walnuts arises from individuals that have developed on the green apples or galls of the California gall fly, *Andricus californicus* (Bassett) which occur in abundance in oak trees.

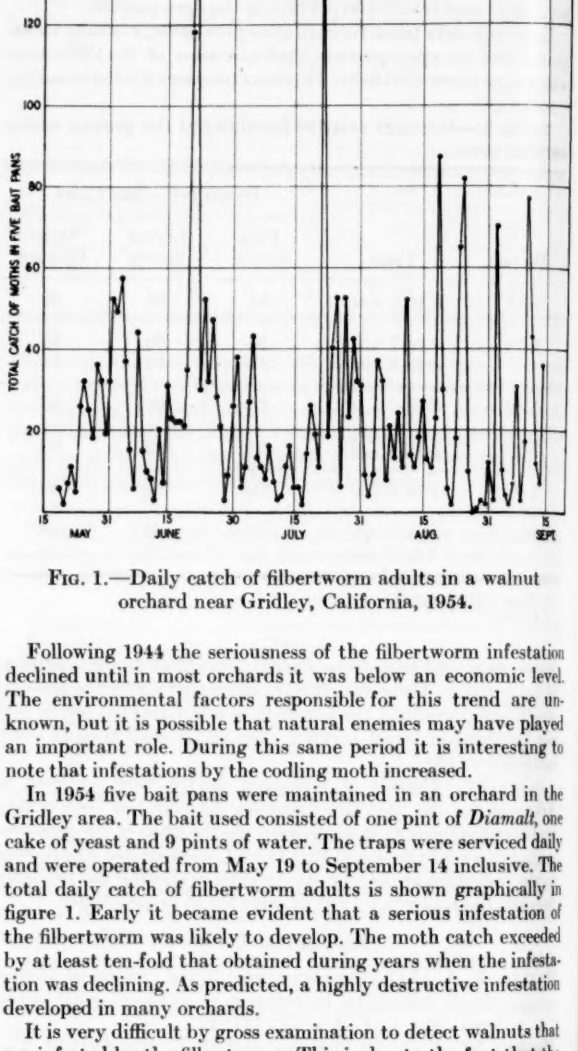

FIG. 1.—Daily catch of filbertworm adults in a walnut orchard near Gridley, California, 1954.

Following 1944 the seriousness of the filbertworm infestation declined until in most orchards it was below an economic level. The environmental factors responsible for this trend are unknown, but it is possible that natural enemies may have played an important role. During this same period it is interesting to note that infestations by the codling moth increased.

In 1954 five bait pans were maintained in an orchard in the Gridley area. The bait used consisted of one pint of *Diamalt*, one cake of yeast and 9 pints of water. The traps were serviced daily and were operated from May 19 to September 14 inclusive. The total daily catch of filbertworm adults is shown graphically in figure 1. Early it became evident that a serious infestation of the filbertworm was likely to develop. The moth catch exceeded by at least ten-fold that obtained during years when the infestation was declining. As predicted, a highly destructive infestation developed in many orchards.

It is very difficult by gross examination to detect walnuts that are infested by the filbertworm. This is due to the fact that the caterpillars do not enter the nuts until the latter are mature or nearly so. By this time a small suture may occur at the stem end through which the small caterpillars easily penetrate without leaving any or very little frass as telltale evidence. As a result the degree of infestation can only be accurately determined by cracking the nuts and carefully examining them.

Many growers who thought they had delivered good quality nuts to the packing house were greatly surprised when they received reports that upward to 30 per cent or more of their crop was infested. The moth population was so large during the critical period from mid-August until the end of the season, that even where early harvest was practiced a considerable number of the nuts were infested. Although serious damage was fairly well limited to portions of the Sacramento Valley, an increase in the infestation of the pest was observed in all areas of Northern California where walnut insect investigations were conducted. Ecological investigations are needed to determine the reasons

[1] Accepted for publication January 19, 1955.
[2] In California this insect is more often called the Catalina cherry moth.

for the wide fluctuations that occur in the infestation of the filbertworm in walnuts. However, based on past experience the intensity of the attack can be expected to decline from the high level reached in 1954. It is also evident that there is a real need for the development of an effective spray program that can be directed against the pest in late season. Early harvest and rapid curing of the crop are helpful in reducing the amount of damage, but under conditions of severe infestation are not sufficient to keep injury below an economic level.

ACKNOWLEDGEMENTS.—We would like to express our appreciation and thanks to L. Z. Loar who maintained and serviced the bait pans. For field and laboratory assistance we wish to thank Ross R. Sanborn, Farm Advisor for Butte County, Howard Wiedman, Extension Assistant for Butte County and Earl Oatman, Graduate Research Assistant, University of California, Berkeley.

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Crossbreeding Beet Leafhoppers from California and French Morocco[1]

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An outbreak of the beet leafhopper, *Circulifer tenellus* (Baker), in 1950 resulted in severe losses to growers of melons and early tomatoes in California. These growers requested that additional control measures be devised to help reduce losses resulting from the spread of curly top virus. The California State Legislature subsequently appropriated an additional $250,000 for control work (Armitage 1952). The bulk of this appropriation was used to intensify the regular program consisting of the application of insecticides and eradication of Russian thistle in the western foothill areas of the San Joaquin Valley. However, a portion of the money was set aside to investigate the possibility of biological control. This involved the search in the Mediterranean area for parasites which attack it or its close relatives.

The beet leafhopper was known as *Eutettix tenellus* (Baker) for more than 50 years, although it generally was agreed among taxonomists of the group that *tenellus* was not a close relative of the genus *Eutettix* a group of robust leafhoppers usually found on oak. Since the generic affinities of the beet leafhopper were not known, *tenellus* was retained in the genus *Eutettix* for convenience. Recently, however, Oman (1948) indicated that a group of leafhoppers, occurring in the Mediterranean area, belonging to the genus *Circulifer* had male genitalia characters of the same type as those of the beet leafhopper. Oman, therefore, placed *tenellus* in the genus *Circulifer*.

Thus in 1951 as part of the preliminary biological control investigation, Frazier (1953) surveyed the Mediterranean area for leafhoppers of the genus *Circulifer*. He collected several species belonging to this genus, among which was a species believed to be the beet leafhopper, *Circulifer tenellus* (Baker), (Young & Frazier 1954). Male genitalia dissected from these Mediterranean specimens and from specimens collected in Western United States agreed so closely in form that the evidence seemed almost conclusive that these leafhoppers collected from different hemispheres represented a single species. However, the Mediterranean collections made by Frazier (1953) indicated that this species was not found on sugar beets in that area of the world and more evidence to identify the suspected *tenellus* was desirable.

The continuation of the search for beet leafhopper parasites was made in the Mediterranean region by J. K. Holloway in 1952 and 1953 and by C. B. Huffaker in 1954 (Huffaker *et al.* 1954) made it possible to further establish the relationships of the old and new world forms of *C. tenellus*. Crossbreeding tests were conducted with leafhoppers from French Morocco and California in an attempt to obtain experimental evidence that this leafhopper collected from different parts of the world was actually a single species. In addition, the leafhoppers from North Africa were tested for natural infectivity and for ability to transmit curly top virus.

EXPERIMENTAL RESULTS.—Huffaker collected male specimens believed to be beet leafhoppers, *Circulifer tenellus* (Baker) at El Khemis near Agadir, French Morocco on *Plantago* and cruciferous weeds *Mathiola*, *Malcolmia*, and *Alyssum* and shipped 35 of them by air express to the quarantine station of the Department of Biological Control at Albany, California. The Bureau of Entomology and Plant Quarantine, Agricultural Research Administration of the United States Department of Agriculture had given permission to send only male beet leaf hoppers because males were considered less hazardous than females if some of the leafhoppers should escape during transit.

Fifteen of the leafhoppers were still alive on arrival. The carton containing the insects was opened in a parasite emergence cage with cloth sleeves through which the insects could be manipulated in the quarantine room. The insects were maintained under strict quarantine conditions during the duration of these experiments and no living specimens were removed fron the quarantine room. Fourteen of the leafhoppers were transferred singly to fourteen healthy sugar beet test plants for a period of 2 days to determine if they were naturally infective with curly top virus. The results of these tests were symptomatologically negative, indicating that this group of insects was not carrying the virus under natural conditions in French Morocco.

Following the natural infectivity tests, 11 surviving French Morocco male leafhoppers were removed from the test plants and transferred to curly top infected sugar beets for 2 days. Seven of the 11 survived, and these were transferred individually to seven healthy sugar beet seedlings, each enclosed in a separate cloth lined cage. To each cage containing a single male leafhopper from French Morocco was added a previously unmated noninfective California female beet leafhopper.

Six of the seven crosses were successful and resulted in 4, 10, 20, 34, 40 and 78 leafhopper nymphs respectively. The leafhopper rearing conditions were not considered ideal in the quarantine rooms because of poor light and humidity conditions for the growth of sugar beets. Under more favorable conditions the number of offspring might have been much greater.

The adults from the F_1 generation were allowed to inbreed to determine if they were fertile, and five of the six crosses were successful, resulting in the development of nymphs of the F_2 generation. The F_2 generation was small in number, but this was considered to be due primarily to the lack of light and to infestation of some of the sugar beets with red spider.

In summary, it may be said that the curly top virus was transmitted successfully by four of the seven French Morocco male leafhoppers. The F_1 leafhoppers of two of the crosses transmitted curly top. One F_1 population infected one sugar beet, while a second population transmitted curly top virus to seven of eight sugar beets on which they fed.

The results of the crossbreeding experiments indicate that the mating of the French Morocco males with previously unmated California females produced a fertile F_1 generation. The fact that French Morocco males and F_1 individuals were vectors of curly top virus is additional evidence that the African leafhoppers are the same species as the North American beet leafhopper, *Circulifer tenellus* (Baker).

[1] Accepted for publication January 24, 1955.

The evidence suggest that the beet leafhopper is a native species of the Mediterranean area where its close relatives occur and that it represents a species which was probably introduced into Western North America possibly by the early explorers or settlers. Since all the available information indicates that the curly top virus does not occur in the Mediterranean region, it would appear that this virus is a native to the Western Hemisphere. The highest densities of beet leafhoppers encountered by Huffaker in French Morocco, Algeria or Egypt were characteristically on lamb's quarters, *Chenopodium* sp., growing in old dry abandoned tomato fields adjacent to the desert near Giza, Egypt. None of the tomatoes showed any symptoms of curly top disease, although a hundred or more tomato fields of all ages were examined. Also, the tomato production for the Cairo market is concentrated in the exact area of highest density of *C. tenellus;* yet, there is no history of trouble from curly top disease. Before the introduction of the beet leafhopper to Western North America the virus may have been carried by some vector such as possibly an *Agallian* species since *Agallian* leafhoppers are known to transmit South American strains of the curly top virus.

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Control of Maggots in Turkey Dung with Malathion[1]

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The control of flies breeding in turkey dung has been a difficult problem on Wisconsin turkey ranches. Accumulations of dung beneath porches or under wire floor racks are removed only with considerable difficulty, and are usually permitted to build up for a period of several months or until birds are placed on range. Space sprays applied within turkey shelters or residual insecticides applied to walls and fixtures are ineffective, since the breeding potential under optimum conditions considerably exceed the adult kill obtained. A series of chemicals was tested on fly breeding media under field and laboratory conditions, and it was determined that malathion was effective as a larvicide for direct application on turkey dung.

Field Studies.—Accumulations of turkey dung 3 to 5 inches in depth beneath porches and under wire racks within shelters were treated with a 2% malathion emulsion by means of a sprinkling can. Application was at the rate of 2 and 4 gallons per 50 square feet. Maggots breeding under these conditions were *Musca domestica* and *Phaenicia sericata.*

Within an hour following application, all surface maggots were immobilized. Mature maggots within the dung mass were still active, although second instar maggots were affected. Excellent control of all maggots was observed 24 hours after application, and very few living maggots were found in any of the four 50-square-foot areas treated. Areas treated with 2 gallons of emulsion were as effectively controlled as those treated with 4 gallons of emulsion. Little control was observed in plots treated with 2 gallons of TEPP (8 mls. 40% TEPP per gallon) and maggot populations in the check plots were unchanged.

Laboratory Studies.—House flies were reared in 1-gallon, waxed ice cream containers filled with a standard rearing media, and the solid covers replaced with cheese cloth. The numbers of flies emerging from the treated cultures compared with check cultures were used as an index of larvicidal effect. Emulsions varying in concentration from 0.5 to 4 per cent malathion were applied to the media surface as a wet spray at the rate of 28 mls. per square foot (in the above field studies, the rate of applications was approximately 37 mls. per square foot). Test cultures were given one surface application. Four series of duplicated tests were made with maggots at 1, 2, 3 and 4 days of age. Maggots were reared under optimum conditions with the result that pupation was completed 5 days after introduction of eggs. The results of these tests are summarized in table 1.

Table 1.—House fly emergence following surface treatment of media with malathion emulsion.

Per Cent Malathion	Age of Maggots in Days at Time of Treatment			
	1	2	3	4
4	0	0	2	330[a]
3	0	0	14	61
2	0	0	15	53
1	0	1	27	661[a]
0.5	31	1	378	95
0 (control)	1919	1679	1947	1411

[a] Large numbers of pupae at time of treatment.

Surface applications of malathion were effective in reducing maggot populations in treated cultures. First and second instar maggots were very susceptible to malathion. Maggots in the late 3rd instar were more resistant to malathion and the chemical had relatively little effect on pupae.

Toxicity Studies.—The effect of malathion on young turkeys is an important consideration when it is used under conditions in which the birds might be expected to come in direct contact with freshly treated wire or manure. One-month-old white and bronze turkey poults were exposed to malathion for a period of 10 weeks. The white poults were divided into three lots of 5 birds each. One lot served as an untreated check. Poults in a second lot were permitted to run on wire and manure which was treated weekly with 2% malathion emulsion applied with a sprinkling can at the rate of 2 gallons per 50 square feet. In the third lot, when the poults were 2 months old, feed racks and water trays were not removed from the floor or covered during treatment and were directly contaminated with malathion. The bronze poults were divided into two lots of six birds each. One lot served as an untreated check, and in the second lot the wire and manure were treated with malathion at weekly intervals. The legs of all birds confined in treated pens were dipped in malathion emulsion at each weekly treatment period.

During the entire exposure period, none of the birds appeared (on gross examination) to be adversely affected by the malathion treatments. In comparison with the checks, activity of the birds in treated pens was not depressed or unusually agitated, and they appeared to develop normally. The birds freely ingested feed and water contaminated with malathion without apparent effect over a period of 6 weeks.

Summary.—Field and laboratory experiments demonstrated that malathion was an effective larvicide for the control of house fly maggots. Surface applications to manure of a 2% water emulsion at the rate of 2 gallons per 50 square feet gave satisfactory

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maggot control. No evidence of toxicity resulted from exposure of turkey poults to treated manure and wire surfaces for a period of 10 weeks, or contamination of feed and water over a period of 6 weeks.

Rotenone Resistance in the Mexican Bean Beetle[1]

CHARLES H. BRETT and ROSS W. BRUBAKER[2]

During the past several years it has been noted that rotenone was providing ineffective control for the Mexican bean beetle in some of the important bean growing areas in the mountains of North Carolina. In 1951 a cooperative testing program was set up between the U.S.D.A. and the North Carolina Agricultural Experiment Station to measure this factor. The general resistance of beetles in the Hendersonville, N. C. area (Mills River, N. C.) compared with those at Norfolk, Virginia, can be seen in table 1.

Table 1.—Comparative susceptibility of the Mexican bean beetle to rotenone dust applied at the rate of 20 to 25 lbs. per acre in the field.

YEAR	DUST CONC. (PER CENT)	CONTROL FACTOR	
		Norfolk, Virginia	Mills River, North Carolina
1951	0.75	95	70
1953	1.0	98	86
1954	1.0	96	62

The total number of large larvae and pupae from four replicated plots were counted at the time beans were being picked. The control factor was calculated by dividing the number of insects in the treated plots by the number in the check plots. This was multiplied by 100 and the resultant was subtracted from 100. The control factor at Norfolk, Virginia, was consistently higher than at Mills River, N. C.

Turner (1953) in Connecticut found a greater difference between the toxicity of methoxychlor and rotenone to Mexican bean beetles in 1952 than there was in 1945. He also showed that it was necessary to increase dosages of rotenone from 0.09 per cent in 1942 to 0.5 per cent in 1952 in order to obtain an L.D. 90.

Laboratory tests were conducted at Raleigh in 1954 to make a direct comparison between beetles from the North Carolina mountains where resistance seemed apparent, with bettles from Norfolk where rotenone had consistently given good control. Test insects were third- and fourth-instar larvae collected in the field in both areas on the same day. These were brought to the laboratory where all testing was done at the same time and under the same conditions.

TEST PROCEDURE consisted of placing 50 larvae in a 2-quart glass canning jar. The Kerr self sealing lid had the center removed and replaced with a screen. Two such jars were prepared for each test. Dust applicators had been previously prepared by cutting glass tubing into 5-inch lengths. Each tube was bent at a 45-degree angle. Fifty milligrams of dust was weighed into a tube on an analytical balance. One such tube was prepared for each test. Also, for each jar of insects another similar jar was prepared which contained a bean plant with its roots wrapped in moist cotton enclosed in aluminum foil.

Dust was applied by placing a rubber bulb on one end of the glass tube and ejecting dust into a jar with a single puff. Jars were always in a horizontal position. After about 5 minutes the beetles were transferred to jars containing the untreated plants.

Plants for dipping were prepared as described above. Each plant was completely emersed into the rotenone emulsion, then placed on an absorbent paper and dried for a few minutes. A treated plant was placed in a jar containing untreated beetles.

Table 2.—Laboratory test showing per cent mortality of 3rd or 4th instar larvae of the Mexican bean beetle 48 hours after treatment with rotenone dust.

DUST CONC. (PER CENT)	NORFOLK, VIRGINIA	MILLS RIVER, NORTH CAROLINA
1.0	100	52
0.5	89	19
0.25	68	12
0.0	3	3

READINGS were made at regular intervals. Each of the two replicates were checked by a different observer. Data from this experiment are given in tables 2 and 3.

Table 3.—Laboratory test showing per cent mortality to 3rd or 4th instar larvae of the Mexican bean beetle 48 hours after being placed on leaves dipped in rotenone emulsion.

ROTENONE CONC. (PER CENT)	BEETLES COLLECTED IN THE FIELD	
	Norfolk, Virginia	Mills River, North Carolina
0.08	38	18
0.04	22	7
0.02	27	6

Beetles collected at Mills River, North Carolina were taken to the laboratory for propagation. A second experiment was set up comparing third generation offspring of these beetles with field collected beetles from Norfolk, Virginia. Data from this experiment are presented in table 4.

Table 4.—Laboratory test showing per cent mortality to 3rd or 4th instar larvae of the Mexican bean beetle 48 hours after treatment with rotenone dust.

DUST CONCENTRATION (PER CENT)	BEETLES FROM—	
	Norfolk, Virginia. (Field Collected)	Mills River, North Carolina. (F3 Laboratory Reared)
100	100	34
0.5	73	11
0.25	36	5
0.0	1	7

Results from these tests demonstrate a considerable resistance to rotenone by Mexican bean beetles from Mills River, North Carolina, as compared with those from Norfolk, Virginia. This factor is inherited and not a reflection of climatic or other differences. The range of differences between beetles from the two areas in their susceptibility to rotenone is quite consistent in both field and laboratory data. Other materials tested on beetles from Mills River, both in the field (Brett & Brubaker 1953) and laboratory are very effective and are being recommended in this area to replace rotenone.

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[1] Accepted for publication February 2, 1955.

[2] North Carolina Agricultural Experiment Station and U.S.D.A. Agricultural Research Service, Entomology Research Branch, respectively.

EDITORIAL

Insect Name Changing

Changes in the scientific names of insects are irritating, especially in the case of species that are of economic importance. They complicate the search of the literature and they cause misunderstandings. Unfortunately, they are often unavoidable, but perhaps they would be less annoying if the reasons for them were better understood.

Because an insect may be widely distributed, or may become so, its scientific name needs to be in a universal language. Accordingly, it is in Latin or is Latinized. Ideally, the name given an insect at the time of its original description is permanent and universally used, but unfortunately certain factors interfere with the maintenance of that desired stability and common usage. Most important of these is the great and rapid increase in the number of different kinds of insects that are recognized as distinct. In less than 200 years the number has grown from approximately 2,000 to nearly 800,000 and it continues to increase at a swift pace. Many workers in all parts of the world have contributed to this growth, each adding new generic and specific names to the vast assemblage and proposing readjustments in classification. These readjustments may entail the shifting of species from one genus to another, the synonymizing of generic and specific names, the resurrection of previously synonymized names which further study has shown to be valid after all, the correction of misidentifications, and the splitting up of complexes of closely similar species that have long been considered the same. Amid this welter of new proposals and new alignments specialists in all groups have been trying earnestly to establish orderly arrangements and a stable nomenclature.

The need for some control over the naming of animals was recognized very early, and specialists in certain areas or subject matter fields began to establish sets of rules to govern the nomenclature with which they had to deal. It was inevitable that these codes should lead eventually to the formulation of the International Rules of Zoological Nomenclature which were approved in 1901 by the International Congress of Zoology. Since the primary need was to insure that no name should apply to more than one kind of organism the central principle around which the Rules were developed was embodied in the Law of Priority, which declares that "the valid name of any genus or species must be that under which it was first designated." Although the International Commission on Zoological Nomenclature, which is responsible for interpretation of the Rules, has no authority to enforce their adoption by individual zoologists, it was hoped that they would be applied throughout the world and would gradually bring about the much desired uniformity in usage of scientific names. Almost at once, however, opposition arose to the rigid application of the Law of Priority; and in 1913 provision was made for the establishment of an "Official List of Generic Names," designed to preserve certain names of wide and common usage which had entered extensively into the literature of other fields, e.g., medicine and agriculture, but which could not be maintained under strict application of the Law of Priority. The first insect name to be placed on this list was *Musca*, with *domestica* L. as type. By this action permanence of *Musca domestica* L. as the scientific name of the house fly was assured. In keeping with the Commission's determination to hold the number of names on the Official List to a minimum it grew very slowly at first, but in recent years, as the number of zoologists holding out for rigid application of the principle of priority diminished, more and more names have been added. Moreover, a companion Official List of Specific Names has now been established. Thus a considerable number of names that are in conflict with earlier names for the same organisms will be preserved by fiat, but the necessity for changes will by no means be eliminated since various other circumstances may make a name untenable.

As scientific knowledge of insects grows taxonomic work necessarily becomes increasingly critical. The continuous alteration of classifications and the refinement of generic and specific definitions, which are inevitable concomitants of such increase of taxonomic knowledge, produce situations that leave no alternative to the changing of names. An illustration of such unavoidable name changing is that involving the corn earworm (also known as the tomato fruitworm and the bollworm). Not long ago the name *Heliothis obsoleta* (F.) was in general use for this pest. Then it was discovered that the same name had been proposed earlier, and was still being used, for a very different species of Lepidoptera. *Heliothis obsoleta* (F.), as employed for the corn earworm, was a primary homonym and had to be abandoned in favor of *Heliothis armigera* (Hbn.) which was the next available name. Unfortunately, this seems not to be the end of the matter for recently (Common 1953, Australian Journal of Zoology 1:319–344) it has been shown that the name *armigera* applies to an Old World species from which the corn earworm of the Western Hemisphere is distinct. And so it appears that another name will need to be used for this important agricultural pest.

Sometimes lack of uniformity in name usage as between different regions of the world is due to a conservative attitude in certain areas and a slowness to accept changes resulting from restudy and reclassification of the groups involved. The genus *Pectinophora*, for example, was established in 1917 for a segregate of the older genus *Platyedra* including the pink bollworm, but in the Old World *Pectinophora* has not been accepted and *Platyedra gossypiella* (Saund.) continues to be used for that pest. There, too, *Phthorimaea* is still employed as the generic name of the potato tuberworm, although it is a synonym of *Gnorimoschema* and the correct name for the insect is *Gnorimoschema operculella* (Zell.). In the case of the codling moth, however, it is the New World that persists in the use of a name, *Carpocapsa*, which is apparently

incorrect. Such regional disagreements among taxonomists may continue for some time, and are disturbing while they persist, but eventually they are reconciled.

Insect name changing will go on indefinitely but it is to be expected that gradually a substantial measure of stability will be attained for names of those insects, at least, that are of economic importance. The joint efforts of taxonomists and the International Commission on Zoological Nomenclature are directed toward this end. It is to be hoped that meanwhile the field entomologist will be patient in this matter and will not condemn every change announced by taxonomists as something deliberately devised to confuse him, but that he will investigate the reasons and if these appear sound that he will accept the change as a step in the direction of stabilization.

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Changes in Common Names of Insecticides for Use in the Journal of Economic Entomology

Since this list was published in Volume 48(1): 112–115 (February 1955 issue), it has been necessary to make the following changes in names of materials to be used in the JOURNAL:

"Chlorthion" is a proprietary name and should be capitalized.

"Am. Cyanamid 4124" should be substituted for "isochlorthion," a name coined on the mistaken understanding that "Chlorthion" was a common name.

"R-242" should be used instead of "Sulphenone," which is likely to be confused with "Sulfenone," a proprietary name for a different product.

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Committee on Insecticide Terminology,
Entomological Society of America

BOOK REVIEW

REVISION OF THE SPIDER MITE FAMILY TETRANYCHIDAE, by A. Earl Pritchard and Edward W. Baker. 1955. Memoir Series, Pacific Coast Entomological Society, California Academy of Sciences, San Francisco, Calif. 472 pages, 391 figures. Price $10.00.

Agricultural and medical needs during the past decade have spurred systematists to focus attention upon the mites. Contemporary students are well aware that these small arachnids of great economic importance comprise a rich array of species sorely in need of re-definition in all taxonomic categories. Those best known in a general way to agriculturalists are the plant feeding mites of the family Tetranychidae—variously called the spider mites, red spiders or spinning mites. Unfortunately, out of step with the many aspects of control work on spider mites, the identification of species heretofore has been truly a task for but few competent specialists.

This new book on the Tetranychidae by Pritchard and Baker is one of the most comprehensive taxonomic treatises yet to appear for any family group of mites. The scope of the work and the new knowledge presented by these two top-flight authorities should do much to attract and give confidence to new people in regard to the intricacies of spider mite identification. The merits of the book are many; but the originality of the re-descriptions of old and misidentified species seems to transcend its other values. One hundred ninety-nine species are characterized, including 38 new ones and 60 re-descriptions based on original type specimens. Also new synonyms—of which there are many—are largely derived from the study of type material not included in this tally.

Following brief prefatory remarks by Dr. G. W. Wharton and an abridged introduction, the essential business of the book begins on page four. The text is clear, sparing of words and free of monotonous generalizations. Descriptions follow the terse or telegraphic style, and differential diagnoses are provided for most of the taxonomic units.

Keys to females of the large genera of the tribe Tetranychini will be much appreciated by others who have had to make determinations according to profile patterns of male aedeagi. The authors have examined the most intricate anatomical details of chaetotaxy, integumental striae, etc., in order to distinguish between females of this homogeneous tribe. It is also gratifying to have the subfamily Bryobiinae included in a unit work on spider mites. Of interest in respect to revision of genera is the fact that *Paratetranychus*, formerly a large genus, is made a synonym of *Oligonychus*. The question of the name of the much-confused two-spotted mite of agriculture is resolved in favor of *Tetranychus telarius* (Linn.). More than four pages of new and old synonyms are listed for this species, including *T. bimaculatus*, *T. multisetis*, *T. urticae*, and *T. altheae*.

There are 391 clean-cut textfigures. These are meticulously drawn and are excellent of type. The generous use of illustrations to facilitate identification has a very emphatic function in the case of soft-bodied mites such as these because the long-preferred mounting media do not yield permanently preserved type specimens. A minor consequence of the emphasis on illustration introduces a printer's problem of locating figures for best coordination with the text. The authors have carried on the McGregor scheme of comparatively illustrating the aedeagi of males in summary form. Another convenience is a complete index of host plants. An extensive bibliography and an index of species complete the work. The index of species is a bit cumbersome to use since the specific names are listed only under appropriate genera. Synonyms, prior misidentifications, etc. are here indicated in italics.

This monograph in book form will be indispensable to those who are concerned with the taxonomy or identification of spider mites. Advanced or beginning students of mites should discover that the price of the book is small in relation to its value as a constantly useful tool.

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